Test Wells, Square Lake and Wolf Creek Areas Alaska

EXPLORATION OF NAVAL PETROLEUM RESERVE NO. 4 AND ADJACENT AREAS, NORTHERN ALASKA, 1944–53

PART 5, SUBSURFACE GEOLOGY AND ENGINEERING DATA

GEOLOGICAL SURVEY PROFESSIONAL PAPER 305-H

Prepared and published at the request of and in cooperation with the U. S. Department of the Navy, Office of Naval Petroleum and Oil Shale Reserves

Test Wells, Square Lake and Wolf Creek Areas Alaska

By FLORENCE RUCKER COLLINS

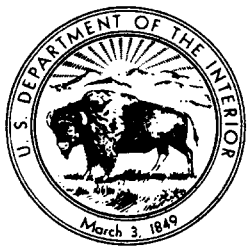
With Micropaleontology of Square Lake Test Well 1 and the Wolf Creek Test Wells, Northern Alaska
By HARLAN R. BERGQUIST

EXPLORATION OF NAVAL PETROLEUM RESERVE NO. 4 AND ADJACENT AREAS, NORTHERN ALASKA, 1944–53

PART 5, SUBSURFACE GEOLOGY AND ENGINEERING DATA

GEOLOGICAL SURVEY PROFESSIONAL PAPER 305-H

Prepared and published at the request of and in cooperation with the U. S. Department of the Navy, Office of Naval Petroleum and Oil Shale Reserves



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1959

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

The U. S. Geological Survey Library has cataloged this publication as follows:

Collins, Florence Rucker.

Test wells, Square Lake and Wolf Creek areas, Alaska. With Micropaleontology of Square Lake test well 1 and the Wolf Creek test wells, northern Alaska, by Harlan R. Bergquist. Washington, U. S. Govt. Print. Off., 1959.

iii, 423–484 p. maps, diagrs. (2 fold. in pocket) tables. 30 cm. (U. S. Geological Survey. Professional paper 305–H. Exploration of Naval Petroleum Reserve No. 4 and adjacent areas, northern Alaska, 1944–53, pt. 5, Subsurface geology and engineering data)

"Prepared and published at the request of and in cooperation with the U. S. Dept. of the Navy, Office of Naval Petroleum and Oil Shale Reserves."

Includes bibliographies.

(Continued on next card)

Collins, Florence Rucker. Test well ... 1959. (Card 2)

1. Borings—Alaska. 2. Micropaleontology. I. Bergquist, Harlan Richard, 1908– II. Title. III. Title: Square Lake and Wolf Creek areas, Alaska. (Series: U. S. Geological Survey. Professional paper 305–H. Series: U. S. Geological Survey. Exploration of Naval Petroleum Reserve No. 4 and adjacent areas, northern Alaska, 1944–53, pt. 5)

553.282

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price $1 (paper cover)

CONTENTS

ILLUSTRATIONS

[Plates 29 and 30 are in pocket]

TEST WELLS, SQUARE LAKE AND WOLF CREEK AREAS, ALASKA

By Florence Rucker Collins

ABSTRACT

Square Lake test well 1 and Wolf Creek test wells 1, 2, and 3 were drilled on 2 anticlines in the Arctic foothills province of northern Alaska. The wells were drilled in 1951 and 1952 as part of the U. S. Navy's program of exploration for oil in Naval Petroleum Reserve No. 4. Rocks of Cretaceous age were penetrated in both anticlines. Some of the sands penetrated were found to contain small noncommercial amounts of gas and oil, and the wells were abandoned. This report includes geologic, paleontologic, logistic, and engineering data obtained in drilling the tests; graphic logs are included to supplement the text.

INTRODUCTION

Square Lake test well 1 and the three test wells on the Wolf Creek anticline are on structural features in the northern foothills section of the Arctic foothills province of northern Alaska, north of the central part of the Brooks Range (fig. 33). They were drilled by Arctic Contractors in 1951 and 1952 as part of the U. S. Navy's program of exploration for oil in Naval Petroleum Reserve No. 4. Square Lake test well 1, on an anticline located by seismograph survey, and the Wolf Creek wells, on an anticline defined by photogeologic and surface mapping, were drilled to test Cretaceous rocks which are oil bearing elsewhere in Naval Petroleum Reserve No. 4. The two anticlines were found to be similar, and both contained gas. The gas volumes were too small to be of present commercial value, and the tests were abandoned.

This report presents detailed geologic and engineer-

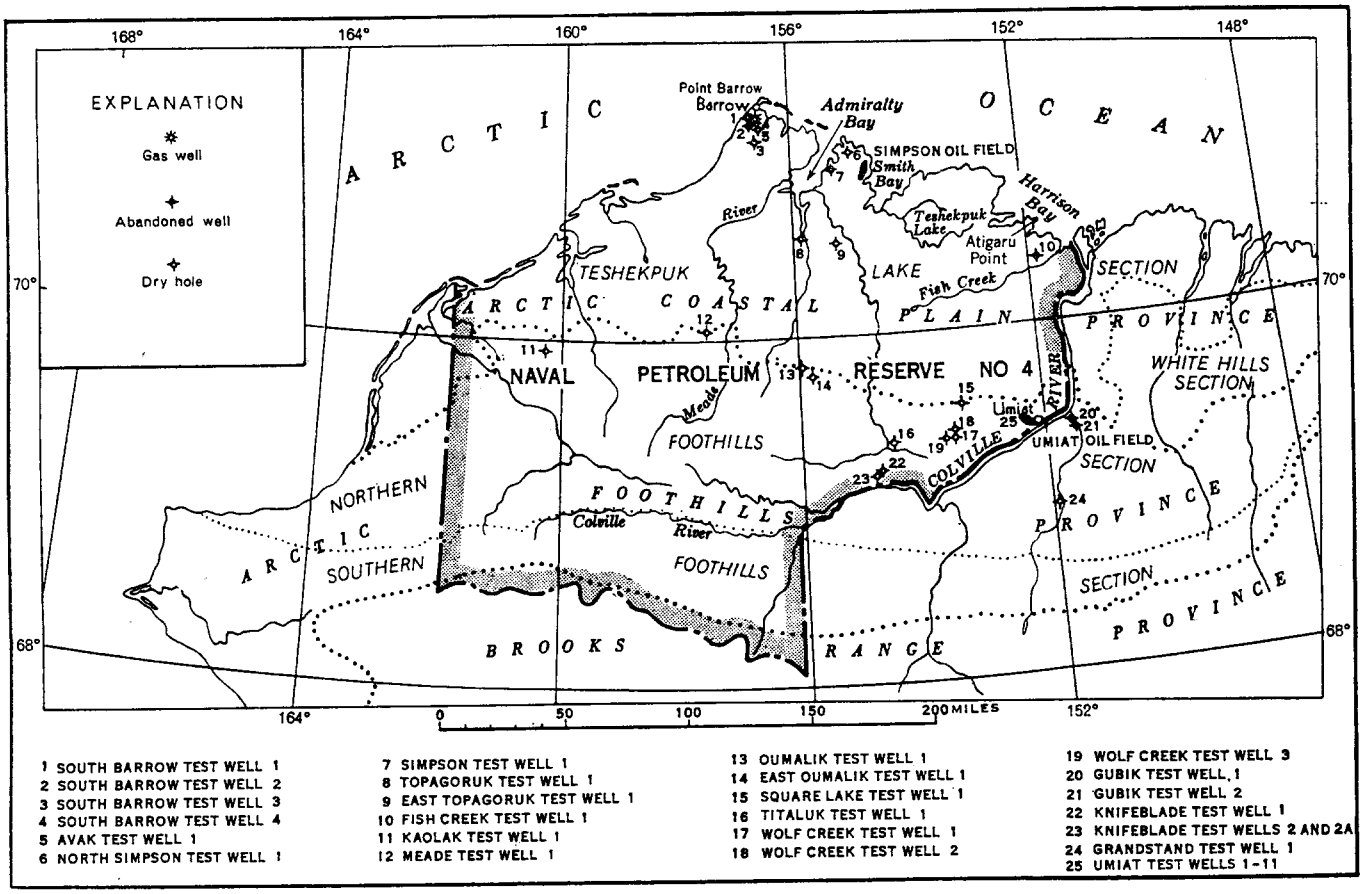


FIGURE 33.—Index map of northern Alaska showing location of test wells and oil fields.

ing data obtained in drilling the four test wells; much of the information is summarized on graphic logs (pls. 29 and 30). Data were compiled in part from information obtained by Arctic Contractors, who drilled the test wells under contract to the U. S. Navy. Additional data were furnished by United Geophysical Co., Inc., the Schlumberger Well Surveying Corp., the National Bureau of Standards, and the U. S. Bureau of Mines. Surface and photogeologic mapping was done by geologists of the U. S. Geological Survey. Survey geologists also described the cores and ditch samples, made microfaunal studies, and determined porosity and permeability in the Survey's laboratory in Fairbanks, Alaska. Microfossils and faunal zones were determined by Harlan R. Bergquist, and the stratigraphic distribution of fossils in the test wells of northern Alaska will be presented by him. Invertebrate megafossils were identified by Roland W. Brown. The heavy-mineral data are part of a regional study of the heavy-mineral zones by R. H. Morris. The help of many other engineers, geophysicists, and geologists connected with the above organizations is gratefully acknowledged.

SQUARE LAKE TEST WELL 1

Approximate location: Lat 69°34′ N., long 153°18′ W.
Elevation: Ground, 324 feet; kelly bushing, 340 feet.
Spudded: January 26, 1952.
Completed: April 18, 1952; plugged and abandoned.
Total depth: 3,987 feet.

Square Lake test well 1 was drilled to test Cretaceous rocks on an anticline defined by United Geophysical Co., Inc., by reflection seismograph in 1951. It is about 145 miles southeast of Barrow on the north edge of the northern foothills section of the Arctic foothills province. The area immediately surrounding the test has less than 50 feet of relief, and the region north of the well is flat, marshy, and dotted with lakes connected by small meandering streams (fig. 34). A few miles south and east of the test, low hills rise about 500 feet above the lowland. The coastal plain is mantled with marine sand deposits of Pleistocene age, and Upper Cretaceous rocks crop out in the hills. The location of the test well is only approximate, as its latitude and longitude were not accurately established. The location of the site with respect to the seismic lines run by United Geophysical Co., Inc., has been carefully determined, however; and the hole is correctly located with respect to the structure contours on figure 34.

Beds dip gently away from the crest of the anticline, and contours drawn by United Geophysical Co., Inc., on a seismic horizon at a depth of 3,000 feet show a vertical closure of much more than 200 feet enclosing an area of about 24 square miles.

The test well is on the northeast side of the east-trending anticline, about 75 feet structurally lower than the apex. The anticline is on the south flank of a structural basin outlined farther east by the Umiat and Gubik anticlines and to the west by the Oumalik anticline. Regional surveys by United Geophysical Co., Inc., in 1947 show that the observed gravity decreases westward in the vicinity of the well. The area is also underlain (according to an airborne magnetometer survey made in 1945–46 by the U. S. Navy and the Geological Survey) by the northwestward-plunging end of the largest magnetic anomaly in the region, the center of which nearly coincides with the crest of the Umiat anticline.

Sandstone beds in the Tuluvak tongue of the Prince Creek formation which contain gas at the Gubik field (Robinson, 1958), and sandstone beds of the Nanushuk group which produce oil and gas at Umiat (Collins, 1958), are nonpetroliferous in this test. Formation tests were inconclusive because ice formed in the testing instrument; but two gas-bearing sandstones in the Seabee formation, at 1,646–1,675 feet and 1,835–1,860 feet, are estimated by Arctic Contractors to contain from 41 to 58 billion cubic feet of gas. Both sandstone beds produced water as well as gas.

STRATIGRAPHY

The following gives the depths at which the stratigraphic units were found in Square Lake test well 1:

Depth (feet)	
16–25	Gubik formation.
25–700	Tuluvak tongue of the Prince Creek formation.
700–1,885	Seabee formation.
1,885–2,475	Ninuluk and Chandler formations, undifferentiated.
2,475–3,987	Grandstand formation.

The well spudded in a thin mantle of alluvium composed of well-rounded sand and gravel made up of clear, white, and yellow quartz and black chert. In the first sample, from 30 feet, rocks from Cretaceous strata as well as surface material were recovered.

In this well the Tuluvak tongue of the nonmarine Prince Creek formation (Colville group, Upper Cretaceous) underlies the alluvium. This sequence of beds is composed primarily of sandstone, with some shale, and is characterized by a large amount of bentonite and some coal. The sandstone is light to medium light gray, silty, and micaceous and commonly has a very bentonitic matrix which makes most of it impermeable. Carbonate minerals, which are probably cementing material, range from 0 to 30 percent; in some places the amount changes abruptly. The very calcareous parts are lighter gray than the noncalcareous ones. Most of the rock is impermeable to air, and the effective poros-

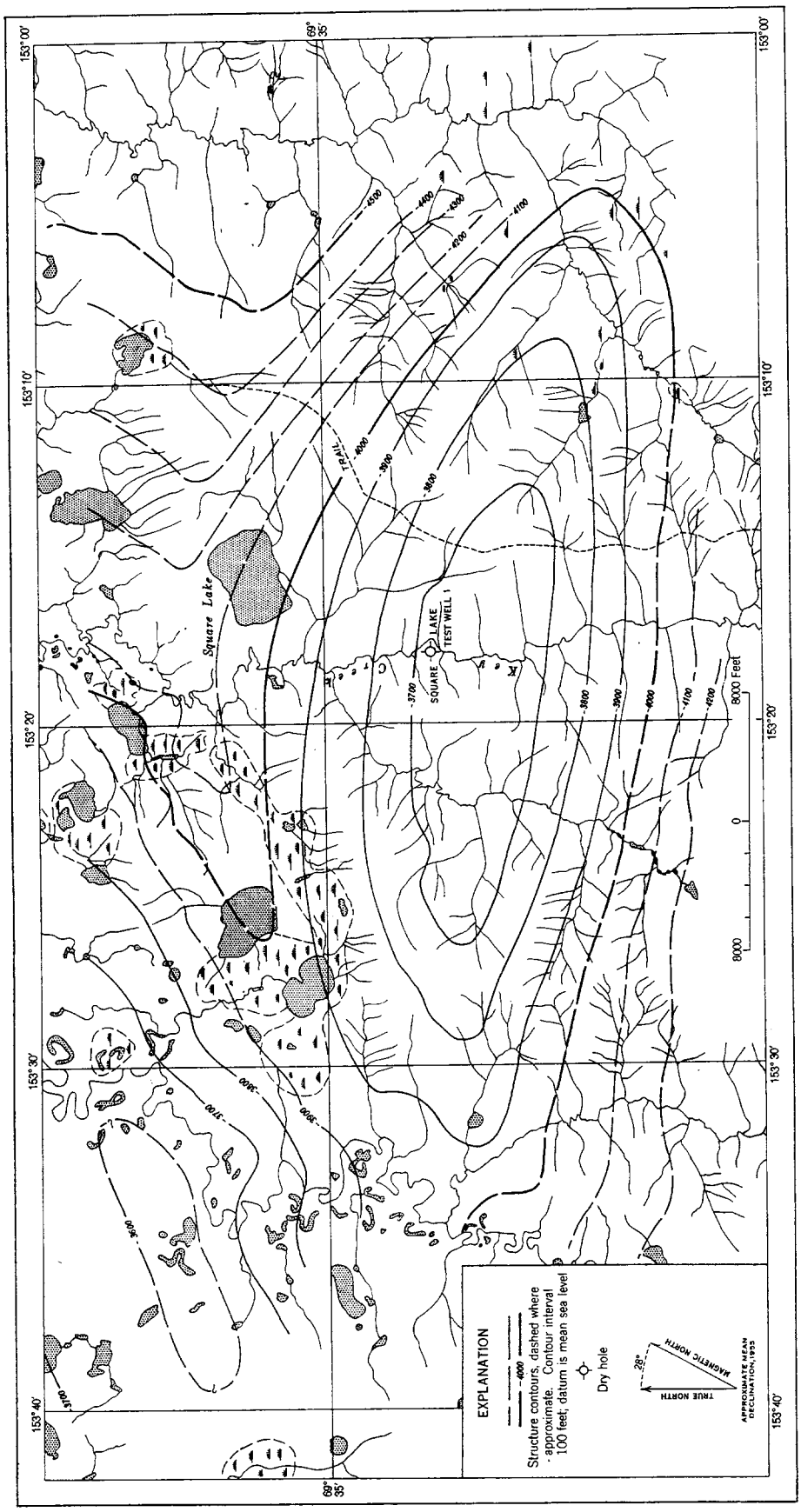


FIGURE 34.—Structure-contour map of Square Lake anticline drawn by United Geophysical Co., Inc., on a seismic horizon in Cretaceous rocks.

ity ranges from 1.9 to 23.2 percent. The sand is very fine to medium grained, and the particles are angular to subrounded clear and white quartz with some white and gray chert and coal fragments. The coarser sandstone beds commonly contain enough dark grains to give them a salt and pepper appearance. Rare siltstone beds are similar to the sandstone. Most of the clay shale is medium to medium light gray, silty in part, and bentonitic, with thin beds and laminae of siltstone. A minor amount of clay shale, commonly associated with coal, is black and carbonaceous. Bentonite is present both as a conspicuous constituent of some shale, siltstone, and sandstone beds, and as laminae or beds as much as 2 feet 8 inches thick. The beds of bentonite are grayish or yellowish white and friable; some are argillaceous and silty. They commonly contain rare to abundant particles of carbonaceous material and minute biotite flakes. Thin coal beds (the thickest cored was 1 foot 3 inches) are present at several depths. Coaly partings were noted in many sandstone beds, and carbonized plant fragments are common in some beds of shale. The bottom of the Prince Creek formation is placed at 700 feet, at the base of the sequence dominated by sandstone. A bed of shale at 522–550 feet contains a few Foraminifera. (See p. 479.)

Below the Prince Creek formation the well entered the marine Seabee formation of the Colville group. The upper part of this formation consists of about 440 feet of bentonitic medium-gray clay shale and is separated from several hundred feet of darker harder less bentonitic shale by 50 feet of light-gray fine-grained slightly bentonitic partly calcareous sandstone. Thin beds of bentonite are very rare in the upper shale, which also contains a few thin beds of siltstone. The darker shale in the lower part of the formation is slightly silty, with silty laminae and beds of medium-gray siltstone that are thicker and somewhat more common than those in the upper part of the shale. Below the base of the lower shale at 1,630 feet are 2 beds of sandstone 120 and 45 feet thick. The upper sandstone bed is light to medium light gray, fine to medium grained, silty, and slightly to very argillaceous; the lower, thinner bed is calcareous. Air permeability of the sandstone is low, ranging from impermeable to 43 millidarcys; and the effective porosity is 10.3 to 20.4 percent. The sand is composed of angular to subangular clear and white quartz, with a few dark rock fragments and chert; mica is rare. These sandstone beds, both of which contain gas, are separated by 140 feet of medium-dark-gray clay shale which is similar to the overlying beds. Beneath the lower sandstone are thin beds of clay shale and siltstone, a 1-inch bed of yellowish-gray clay ironstone, and, marking the base of the formation at 1,885 feet, a thin conglomerate of rounded black chert pebbles one-eighth- to one-quarter inch in diameter.

The top of the Nanushuk group is marked by an abundance of *Trochammina rutherfordi* Stelck and Wall, and *Gaudryina canadensis* Cushman (see p. 480) just below the top of the conglomerate. These two species of Foraminifera are characteristic of the Ninuluk formation, the uppermost formation of the group. In this well the contact between the Ninuluk formation (Upper Cretaceous) and the underlying nonmarine Chandler formation (Lower Cretaceous and Upper Cretaceous) cannot be determined definitely, although a 75–foot interval of sandstone containing a few thin beds of clay shale probably represents the Ninuluk formation. Beneath this sandstone, in descending order, are 10 feet of siltstone, about 200 feet of clay shale with a few thin beds of sandstone, and approximately 500 feet of interbedded sandstone and clay shale. These beds contain essentially no marine fossils, although some contain clay ironstone nodules and laminae of coal and carbonaceous plant fragments. The entire sequence, from 1,885 to 2,475 feet, makes up the Ninuluk and Chandler formations, undifferentiated. The base of this unit is the basal sandstone of the nonfossiliferous sequence.

The apperance of the *Verneuilinoides borealis* microfauna (see p. 480) in the shale beneath the Chandler formation indicates the presence of the marine beds of the Grandstand formation (Nanushuk group, Lower Cretaceous), consisting of interbedded sandstone and shale alternating with thick, massive beds of sandstone. The clay shale is medium dark gray, micaceous in part, slightly to very silty, and has laminae of medium-light-gray siltstone within it. The thin beds of sandstone are medium light gray, silty, argillaceous, and commonly noncalcareous. Five massive sandstone beds, 50 to 125 feet thick, were penetrated in the lower 1,000 feet of the hole. These sandstones are medium light gray, fine to very fine grained, slightly to very silty, and slightly to very calcareous in a few short intervals. The upper sands are somewhat coarser, less silty and argillaceous, and more calcareous than the lower sands, and the uppermost bed is the only one which has permeability (1.7 to 6.8 millidarcys). Porosity is low, ranging from 2.5 to 12.9 percent; the uppermost bed is the most porous of the group. The sand is composed of angular to subrounded grains of clear and white quartz, with some chert and rare dark rock fragments. Mica is rare to common. The sandstone beds contain a few laminae and thin beds of clay shale; carbonaceous partings are rare. An intraformational conglomerate of claystone fragments is present at 3,714 feet, and swirly bedding is at 3,190 feet. Very faint oil stains

were noted in a few of the sandstone beds, but tests recovered only drilling mud. The beds are separated by from 20 to 150 feet of medium-dark-gray clay shale with thin beds of siltstone and sandstone. Between the base of the lowest massive sandstone and the bottom of the hole is an 80-foot interval of shale which may be in either the Grandstand or the Topagoruk formation. The two are distinguished only by the thicker, more massive sandstone beds in the upper formation; and as the presence or absence of sandstone below the bottom of the hole is uncertain, this shale is included in the Grandstand formation.

DESCRIPTION OF CORES AND CUTTINGS

Descriptions of the rocks penetrated in Square Lake test well 1 are based on examinations of cores and cutting samples. Composition as shown on the graphic logs, however, is determined in part by an interpretation of the electric log, and hence may differ slightly from the written description. The material was described dry, and colors were determined by comparison with the Rock Color Chart (Goddard and others 1948). The depths were measured from the top of the kelly bushing.

"Clay ironstone" is a yellowish-gray to grayish-yellow dense hard argillaceous rock with conchoidal fracture; it is sideritic, and usually reacts with cold dilute hydrochloric acid.

Abundance of microfossil specimens mentioned at the beginning of each core description is defined as follows: 1–4, very rare; 5–11, rare; 12–25, common; 26–50, abundant; more than 50, very abundant.

Lithologic description

[Where no core is listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
----	0–16	Kelly bushing to ground level.
----	16–30	No sample.
----	30	Sand and gravel; composed of well-rounded clear white and yellow quartz and black chert. Black shiny, blocky-facturing coal is also present. A few pieces of medium-light-gray clay shale are slightly to very silty, micaceous, noncalcareous, and slightly bentonitic. Rare clay ironstone is light yellowish gray. Top of Tuluvak tongue of Prince Creek formation at 25 ft. Samples to 130 ft contain a large amount surface gravel; this is not included in description below.
----	30–70	Clay shale, light-gray, bentonitic; very fine-grained angular white quartz sand; also coal.
----	70–80	Clay shale and coal.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	80–130	Clay shale, with some coal; small amount white very fine-grained slightly bentonitic sandstone in lower 10 ft.
----	130–140	Clay shale, light-gray; black coaly clay shale; and light-gray fine- to medium-grained bentonitic noncalcareous very slightly micaceous sandstone. Electric log indicates sandstone throughout interval.
----	140–150	Clay shale, light-gray, nonmicaceous, bentonitic, slightly silty in part.
----	150–160	Sandstone, light-gray, very fine-grained, noncalcareous; very slightly bentonitic; some clay shale.
----	160–170	Clay shale, medium-gray, very silty, nonbentonitic.
----	170–200	Clay shale, with some white bentonite and small amount black shale.
1	200–212	Recovered 5 ft: Microfossils absent. 9 in., drilling mud with ½-in. fragments of medium-gray clay shale. 2 in., coal, black, dull; poor shaly to blocky cleavage. 4 in., bentonite, grayish-white, argillaceous; with very rare silt-sized flakes of biotite and coal. 4 in., coal, black, dull to shiny; shaly cleavage; ½-in. bentonite beds as above. 4 in., bentonite, light-olive-gray, very argillaceous, slightly calcareous. 2 in., coal, as above. 2 ft 3 in., coal, interlaminated with black carbonaceous shale. 8 in., claystone, medium-gray, very bentonitic, noncalcareous; slightly waxy luster.
----	212–220	Coal and black shale.
----	220–235	Sandstone, light-gray, fine-grained, noncalcareous, nonbentonitic.
2	235–255	Recovered 19 ft: Microfossils absent. 5 ft, sandstone, medium-light-gray, medium-grained, salt and pepper, slightly argillaceous, slightly to very calcareous, massive; very rare coaly patches. Sand grains are angular to subrounded white and clear quartz with some white and gray chert, and coal particles; dark rock fragments and mica are rare. At 237 ft effective porosity 15.5 percent, and carbonate content 29.1 percent by weight; rock is impermeable to air. 5 in., sandstone, light-gray, fine-grained, argillaceous, very slightly calcareous. 4 ft 7 in., sandstone, as in top of core, medium-grained; grades to fine grained with depth. 1 ft 3 in., sandstone, salt and pepper as above, medium-grained.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		3 ft 8 in., sandstone, light-gray, fine-grained, slightly to very calcareous; common faint-yellowish-gray silty calcareous streaks dipping approximately 22°. At 247 ft rock impermeable to air but has effective porosity of 12.4 percent.
		2 in., siltstone, light-gray, bentonitic; medium-dark-gray clay laminae dipping 17° (cross bedding?).
		7 in., sandstone, very fine-grained, argillaceous, noncalcareous, bentonitic; very rare carbonaceous streaks.
		5 in., clay shale, medium-gray, noncalcareous, slightly bentonitic; blocky to poor shaly cleavage; grades to argillaceous bentonitic medium-light-gray siltstone with clay laminae.
		2 ft 9 in., sandstone, light-gray, very fine-grained, very argillaceous, slightly to noncalcareous; yellowish-gray siltstone streaks and rare carbonaceous patches; there are 2-in. beds of medium-light-gray noncalcareous clay shale at 253 and 254 ft.
		2 in., clay shale fragments, medium-gray, nonsilty, noncalcareous; abundant specks of coaly material.
3	255–274	Recovered 18 ft: Microfossils absent.
		7 in., coal particles and clay shale, as at base of core 2.
		8 in., coal, black, dull to shiny; shaly to blocky fracture; there is a ½-in. bed of medium-gray medium-grained very calcareous sandstone at top.
		1 ft 9 in., clay shale, medium-dark-gray, nonmicaceous, noncalcareous; fair shaly cleavage; carbonaceous streaks and flakes; specks of amber abundant in upper part but grade to absent at base. Slickensides on some surfaces.
		1 ft, claystone, medium-gray, very bentonitic; rare minute carbonaceous particles.
		2 ft 8 in., bentonite, grayish-white, slightly silty; very silty rare minute carbonaceous particles, with abundant minute biotite and carbonaceous flakes in lower part.
		10 in., claystone, bentonitic, as above.
		4 in., clay shale, medium-gray; individual laminae warped and parted by calcite veins of varying thickness which make up at least half of the rock volume. Clay ironstone patches at top and bottom.
		2 ft, claystone, medium-gray, noncalcareous; medium-gray fissile clay shale and two thin (< 1 in.) beds of shaly coal at 265 ft. Roland W. Brown identified a fragment of *Cissites*? sp., a Cretaceous plant, from 264 ft.
		1 ft 1 in., bentonite, white; 2-in. intervals of black carbonaceous fissile clay shale in center and at base of section.
		1 ft 9 in., clay shale, medium-gray, silty, noncalcareous; rare medium-light-gray silt laminae. Beds lie flat.
		2 in., bentonite, white.
		10 in., clay shale, interlaminated with medium-light-gray noncalcareous siltstone. Grades into unit below.
		3 ft 4 in., claystone, medium-light-gray, medium-dark-gray at base, silty; irregular crossbedded siltstone laminae.
		4 in., coal, black, dull; shaly fracture.
		3 in., clay shale, medium-light-gray, bentonitic, coaly.
		5 in., bentonite, white.
----	274–280	Clay shale, medium-gray, nonbentonitic.
----	280–290	Bentonite, very light-yellowish-gray, very argillaceous; small amount clay shale.
----	290–300	Clay shale, light-gray; small amount clay ironstone.
----	300–330	Clay shale with some sandstone, light-gray, fine-grained, nonbentonitic; very fine-grained very silty sandstone and siltstone in bottom 10 ft. Black carbonaceous plant fragments in shale.
----	330–340	Clay shale, light- to medium-light-gray.
----	340–350	Clay shale and bentonite.
----	350–400	Sandstone, light-gray, fine-grained, noncalcareous, nonbentonitic; light- to medium-gray clay shale.
----	400–410	No sample.
----	410–420	Clay shale, with some sandstone as above.
----	420–430	Sandstone and clay shale as above; small amount medium-light-gray argillaceous dense limestone cut by an aragonite veinlet.
----	430–449	Sandstone, very light-gray, medium- to fine-grained, calcareous, nonbentonitic; some clay shale.
4	449–469	Recovered 20 ft: Microfossils absent.
		1 ft 3 in., coal, black, dull to shiny; shaly cleavage to blocky fracture.
		2 ft 10 in., clay shale, light-olive-gray, noncalcareous, very bentonitic; bentonite decreases with depth. Grades into unit below.
		10 ft 7 in., clay shale, medium-light-gray, fissile; abundant carbonaceous plant fragments, especially in the upper part; coaly fragments of *Metasequoia cuneata* (Newberry) Chaney, (identified by Roland W. Brown), and dicotyledonous plants.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		8 in., claystone, medium-light-gray, noncalcareous.
		4 ft 8 in., clay shale, medium-light-gray; intercalations and thin beds of medium- to medium-light-gray very fine-grained silty bentonitic sandstone that is calcareous in upper part. A few streaks of light-gray fine- to medium-grained very calcareous sandstone in upper 2 ft.
----	469–490	Clay shale, with minor amount of sandstone in upper half and black shale in lower half.
----	490–500	Clay shale, black, coaly; and light-gray clay shale, with minor amount coal.
----	500–512	Sandstone, as in core 5.
5	512–532	Recovered 20 ft: Microfossils rare.
		14 ft 5 in., sandstone, medium-light- to olive-gray, very fine-grained, very silty, very slightly calcareous, very bentonitic. Sand grains are very angular, composed of white quartz, commonly frosted; gray and dark rock fragments; mica is common, pyrite and glauconite absent. At 514 ft effective porosity 15.1 percent, at 525 ft effective porosity 9.4 percent, and carbonate content by weight 17.9 percent; samples from both depths are impermeable.
		2 ft 7 in., clay shale, medium- to medium-light-gray, slightly silty, noncalcareous, very bentonitic. Beds lie flat.
		7 in., sandstone, as above.
		2 ft 5 in., clay shale, as above.
6	532–552	Recovered 18 ft: Microfossils rare.
		1 ft 7 in., sandstone, as in core 5; with 1-in. clay ironstone at base.
		1 ft 5 in., clay shale, as in core 5.
		1 ft 3 in., siltstone; similar to sandstone above.
		13 ft 9 in., clay shale, as above; rare thin beds (< one-half inch thick) of silt and very fine-grained sandstone, and two 10-in. beds of medium-light-gray noncalcareous siltstone, with thin beds of clay shale between 541–542 ft and 546–547 ft.
----	552–570	Sandstone, as in cores 5 and 6.
7	570–590	Recovered 20 ft: Microfossils absent.
		7 ft 10 in., sandstone, medium-light-gray, fine-grained, slightly to very calcareous, very bentonitic; composed of angular to subangular grains of white and clear quartz, and gray and dark rock fragments. Biotite is common. Minute bentonitic streaks; carbonaceous partings are rare. Two calcite streaks in very calcareous rock are between 575–576 ft. At 576 ft effective porosity 14.3 percent; air permeability 9 millidarcys, carbonate content by weight 10.25 percent.
		2 ft 4 in., sandstone, as above, but very fine-grained. Grades into unit below.
		2 ft 6 in., sandstone, fine-grained; as at top of core.
		1 ft 3 in., siltstone, light-gray, sandy, calcareous, bentonitic; common slightly carbonaceous laminae dipping less than 2°.
		5 in., sandstone, fine-grained; as at top of core. Grades to medium grained at base.
		1 ft 5 in., clay shale, light-greenish-gray, noncalcareous, very bentonitic; fragment of *Metasequoia cuneata* (Newberry) Chaney from 585 ft was identified by Roland W. Brown.
		8 in., coal; laminae of black shale.
		3 ft 7 in., claystone, light-greenish-gray, noncalcareous; grades to medium light gray at base; subconchoidal fracture becoming fissile toward base.
8	590–608	Recovered 11 ft: Microfossils absent.
		1 ft 7 in., claystone fragments, medium-dark- to dark-gray; small curved slickensided surfaces on a few pieces.
		4 ft 5 in., siltstone to silty claystone, very light- to light-gray, slightly calcareous, very bentonitic; with rare carbonaceous particles and abundant biotite flakes (some euhedral) on bedding planes. Thin 1- to 2-in. beds of light-gray bentonite. Poor shaly cleavage parallel the bedding suggests the beds lie flat.
		3 ft 11 in., claystone, very bentonitic; grades to argillaceous bentonite; infiltrated with drilling mud. Rock is light to medium light gray, noncalcareous, and has irregular to blocky fracture.
		1 ft 1 in., claystone, medium-light-gray, noncalcareous, hard, dense.
9	608–629	Recovered 20 ft: Microfossils absent.
		Sandstone, light-gray, fine- to medium-grained, bentonitic, massive; very calcareous from 613–615 ft and from 625–629 ft and somewhat lighter colored through calcareous intervals compared with noncalcareous sections above and below. Calcareous sections usually have sharp contacts with over- and underlying beds. Sand is composed of angular to subangular white and clear quartz and gray and dark rock fragments; biotite is common; carbonaceous plant flakes on a few rare partings which dip approximately 12° (cross-

Lithologic description—Continued

Core	Depth (feet)	Remarks
		bedding?). At 611 ft effective porosity 21.8 percent, and air permeability 54 millidarcys. At 627 ft effective porosity 1.9 percent, carbonate content 40.8 percent, and rock is impermeable.
10	629–649	Recovered 19 ft: Microfossils absent. Sandstone, as above; calcareous from 629–630 ft and 634–639 ft; lower part of latter interval is yellowish gray and very calcareous. Rest of core to 649 ft is moderately calcareous. At 632 ft effective porosity 23.2 percent, and air permeability 11 millidarcys. At 641 ft effective porosity 10.9 percent, carbonate content 25.6 percent, and rock is impermeable.
11	649–669	Recovered 20 ft: Microfossils absent. 3 ft 9 in., siltstone, medium-light-gray, argillaceous, noncalcareous, bentonitic; rare particles of coal and mica flakes. Beds lie flat. 8 in., sandstone, light-gray, medium-grained, salt and pepper, argillaceous, noncalcareous. 9 in., clay shale, medium-light-gray, noncalcareous, slightly bentonitic; laminae and intercalations of light-gray noncalcareous slightly to very bentonitic claystone. 3 ft 3 in., siltstone, as above. 2 ft 7 in., claystone, medium-light-gray, slightly silty in part, noncalcareous, bentonitic; blocky to subconchoidal fracture. 9 ft sandstone, light-gray, fine- to medium-grained, salt and pepper, argillaceous, micaceous, noncalcareous; carbonaceous partings are common below 665 ft. At 661 ft an impermeable sample has an effective porosity of 18.2 percent. Beds lie flat.
12	669–689	Recovered 20 ft: Microfossils absent. 19 ft 3 in., siltstone and very fine-grained sandstone, light-gray, noncalcareous, very bentonitic; with common biotite flakes. At 672 ft and at 683 ft effective porosity 17.3 and 11.7 percent, respectively; both samples impermeable. Grades into unit below. 9 in., claystone, light-gray, noncalcareous, very bentonitic; biotite common.
13	689–708	Recovered 19 ft: Microfossils very rare. 10 ft 9 in., claystone, interbedded with siltstone and sandstone, as in core 12; slightly to badly infiltrated with drilling mud. 3 ft 3 in., siltstone, light-gray, slightly calcareous in part, bentonitic. Swirly bedding, marked by irregular steeply dipping clay streaks (and one clay ironstone streak), is between 700–701 ft. Top of Seabee formation at 700 ft. 5 ft, claystone, medium-gray, noncalcareous; interbedded with medium-light-gray very argillaceous noncalcareous bentonitic siltstone. Beds lie flat.
14	708–728	Recovered 20 ft: Microfossils very rare. Clay shale, medium- to medium-light-gray, silty in part, noncalcareous, bentonitic in part; rare medium-light-gray silty streaks and laminae; poor shaly cleavage. Thin beds of sandy silt at 715–16 ft. Rare flakes of carbonized plants. Small round or oval patches (one-sixteenth inch in diameter) of medium-light-gray clay on light-gray silty claystone are common in some parts of core. Laminae of grayish-white bentonite rare. Beds lie flat.
----	728–780	Clay shale, medium- to medium-light-gray.
----	780–810	Clay shale, medium-gray; some medium-light-gray siltstone; white bentonite at 790–800 ft.
----	810–820	Clay shale, medium-gray.
----	820–830	Clay shale, with small amount medium-light-gray slightly calcareous sandstone.
----	830–890	Clay shale, medium-gray, bentonitic.
----	890–942	Clay shale, as above; with some medium-light-gray calcareous bentonitic siltstone.
15	942–960	Recovered 17 ft: Microfossils absent. Claystone, medium- to medium-dark-gray, silty, noncalcareous, very slightly bentonitic; abundant laminae of medium-light-gray siltstone and silty claystone. Poor shaly cleavage in upper part and at base of core. Silty laminae lie flat; one irregular ½-in. streak of sandstone at 950 ft dips approximately 20°.
----	960–980	Clay shale and bentonitic siltstone; minor amount of bentonite in upper 10 ft.
----	980–1, 000	Clay shale, bentonitic; small amount bentonitic siltstone.
----	1, 000–1, 040	Clay shale, medium-gray, noncalcareous, slightly bentonitic; trace of siltstone in bottom 10 ft.
----	1, 040–1, 048	Sandstone, light-gray, fine-grained, salt and pepper, calcareous.
----	1, 048–1, 055	No sample.
16	1, 055–1, 066	Recovered 10 ft: Microfossils absent. 5 in., sandstone, light-gray, fine-grained, noncalcareous, slightly bentonitic. 3 in., claystone, with silt laminae as in core 15. 4 in., sandstone, as above; ¼- by 2-in. clay ironstone nodule at top.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		1 ft 9 in., claystone, medium-light-gray noncalcareous, slightly bentonitic; with a ⅛-in. bed of clay ironstone 2 in. above base, and a 2½-in. sandy claystone bed with abundant carbonaceous partings at base.
		1 ft 5 in., sandstone, light-gray, fine-grained, argillaceous, noncalcareous, bentonitic; composed of angular to subangular clear and white quartz grains with gray and dark rock and chert fragments; biotite is common.
		10 in., claystone, with silt streaks as above.
		5 ft, sandstone, as above; but very calcareous and slightly lighter in color from 1,063–1,065 ft. At 1,063 ft effective porosity 15.4 percent, air permeability 12 millidarcys, carbonate content percent by weight 10.70.
17	1, 066–1, 085	Recovered 19 ft: Microfossils absent.
		3 ft, sandstone, as at base of core 16; becomes less calcareous with depth. At 1,067 ft effective porosity 1.6 percent, carbonate content 47.1 percent by weight, rock is impermeable.
		12 ft, sandstone, as above; numerous 1- and 2-in. claystone beds (as in core 16) which make up approximately 20 percent of the interval; one claystone bed at 1,073 ft is 8 in. thick. At 1,077 ft clay laminae and carbonaceous partings dip 20° to 22°, and some clay streaks indicate swirly bedding. An angular 2-in. fragment of claystone, which has slightly silty laminae, and a thin bed of clay ironstone are at top of swirly bedding, embedded in sandstone.
		4 ft, claystone, as in core 16 above; laminae and thin (2 to 3 in.) beds of silt and very fine-grained sandstone totaling 10 percent of the rock; rare carbonaceous partings in sandstone. Beds lie flat.
18	1, 085–1, 087	Recovered 2 ft: Microfossils absent.
		Claystone, with laminae of silt and sandstone as at base of core 17; a 1-in. interval of rock at 1,086 ft is approximately 50 percent clay shale and 50 percent coaly flakes. Beds lie flat.
----	1, 087–1, 090	No sample.
----	1, 090–1, 100	Clay shale, slightly bentonitic; and bentonitic siltstone with abundant biotite flakes.
	1, 100–1, 130	Clay shale, medium-light-gray, very slightly bentonitic; a minor amount of white bentonite and light-gray argillaceous bentonite.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	1, 130–1, 140	Clay shale, medium-light-gray; a small amount of medium-dark-gray clay shale.
	1, 140–1, 150	Clay shale, medium-dark-gray; a small amount of medium-light-gray clay shale; rare microscopic collophane? balls.
----	1, 150–1, 160	Clay shale, medium-dark-gray; a small amount of medium-gray siltstone.
----	1, 160–1, 200	Clay shale, medium-dark-gray, slightly silty, slightly micaceous, as in core 19.
	1, 200–1, 210	Clay shale; a small amount of white bentonite and some bentonitic slightly calcareous siltstone (contamination from above?).
----	1, 210–1, 240	Clay shale, medium-dark-gray.
----	1, 240–1, 250	Siltstone, medium-light-gray, noncalcareous, slightly bentonitic.
----	1, 250–1, 280	Clay shale, medium-dark-gray, nonbentonitic. Microscopic collophane? balls are rare at 1,260–1,270 ft.
----	1, 280–1, 286	No sample.
19	1, 286–1, 306	Recovered 4 ft: Microfossils abundant.
		Clay shale, medium-dark-gray, slightly micaceous, noncalcareous; abundant discontinuous laminae of medium-light-gray siltstone. Beds lie flat.
----	1, 306–1, 430	Clay shale, medium-dark-gray, as in core 19 above; a small amount of siltstone at 1,310–1,320 and 1,420–1,430 ft, and a trace of bentonite at 1,400–1,420 ft.
----	1, 430–1, 451	Siltstone, olive-gray, sandy, slightly calcareous; a small amount of clay shale.
20	1, 451–1, 468	Recovered 7 ft: Microfossils abundant.
		5 ft 7 in., clay shale, medium-dark-gray, slightly silty, noncalcareous; poor shaly cleavage; silty laminae in lower part, and 2 in. of calcareous claystone at base.
		10 in., siltstone, medium-light-gray, argillaceous, crossbedded, very calcareous; rare clay laminae.
		5 in., clay shale, as above.
		2 in., siltstone, as above.
21	1, 468–1, 478	Recovered 13 ft (including 3 ft from core 20): Microfossils abundant.
		Clay shale, medium-dark-gray, slightly silty and micaceous; abundant thin (1 to 2 in.) beds of calcareous medium- to medium-dark-gray siltstone, and a few ½-in. streaks of clay ironstone. The silt totals 25 percent of the rock. The beds have fair shaly cleavage and lie flat.
----	1, 478–1, 480	No sample.
----	1, 480–1, 490	Siltstone, medium-gray, argillaceous; and medium-dark-gray claystone.
----	1, 490–1, 510	Clay shale, medium-dark-gray.
----	1, 510–1, 520	Siltstone, light-olive-gray, noncalcareous; trace of clay shale.
----	1, 520–1, 550	Clay shale, with trace of siltstone in upper 10 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	1, 550–1, 570	Clay shale, with some siltstone.
----	1, 570–1, 590	Clay shale.
----	1, 590–1, 610	Clay shale and siltstone.
----	1, 610–1, 620	Clay shale, with small amount of siltstone.
----	1, 620–1, 630	Clay shale, with some light-gray fine-grained salt and pepper argillaceous calcareous nonbentonitic sandstone.
----	1, 630–1, 637	Sandstone, as above; with trace of shale and siltstone.
22	1, 637–1, 657	Recovered 12 ft: Microfossils absent. Sandstone, light-gray, fine-grained, silty, noncalcareous, slightly bentonitic; poor shaly cleavage. Sand is composed of angular to subangular white and clear quartz, with a small amount of gray chert and dark rock fragments. At 1,646 ft effective porosity 18.7 percent, air permeability 20 millidarcys, and carbonate content 13.73 percent by weight. Mica is rare, pyrite and glauconite are absent. A 1-ft 9-in. section 4 ft above the base of the interval is slightly coarser, somewhat lighter in color, and calcareous. Beds lie flat.
23	1, 657–1, 675	Recovered 20 ft (including 2 ft of core 22): Microfossils absent. Sandstone, as above, but massive, slightly to very calcareous in part; rare carbonaceous partings in the lower half of the core. Pale-straw-colored cut and very pale-yellow residue in CCl_4 at 1,662 ft. At 1,662 effective porosity 11.6 percent, carbonate content 15.68 percent by weight, and rock is impermeable; at 1,671 ft porosity 10.3 percent, air permeability <1 millidarcy, and carbonate content 13.45 percent by weight.
24	1, 675–1, 695	Recovered 20 ft: Microfossils absent. Sandstone, as in core 22, slightly to very calcareous; slightly coarser (fine- to medium-grained) below 1,686 ft. Beds lie flat. *Inoceramus* shell fragments abundant in a 2-in. interval at the base of the finer sand at 1,686 ft; at 1,685 ft effective porosity 18.3 percent, air permeability 28 millidarcys, and carbonate content 5.85 percent by weight; at 1,687 ft porosity 20.4 percent, permeability 30 millidarcys.
25	1, 695–1, 715	Recovered 19 ft: Microfossils very rare. 12 ft 8 in., sandstone, light- to medium-light-gray, fine-grained, slightly argillaceous, slightly calcareous in part, nonbentonitic. Sandstone is massive except for carbonaceous limonitic very bentonitic laminae which are abundant between 1,697–1,698 ft, and dip 7° or less. Sand is composed of angular to subangular grains of clear and white quartz with a minor amount of gray chert and dark rock fragments. Biotite, muscovite, and chlorite are rare. *Inoceramus* shell fragments as large as 1 in. in diameter, deposited parallel to bedding planes, are scattered throughout. Pale-straw-colored cut, and very pale-yellow residue in CCl_4 at 1,702 ft. At 1,699 ft effective porosity 18.8 percent and air permeability 43 millidarcys. At 1,706 ft porosity 20.2 percent, permeability <1 millidarcy. 7 in., claystone, medium-gray, silty, micaceous, noncalcareous; intercalations of silt and very fine-grained sandstone. Poor shaly cleavage; dips 3° or less. 3 ft, sandstone, medium-light-gray, very fine-grained, argillaceous, moderately calcareous; laminae of medium-gray clay shale. A clay ironstone bed one-half inch thick is at 1,710 ft. 2 ft 9 in., claystone, as above.
26	1, 715–1, 735	Recovered 20 ft: Microfossils absent. 6 in., claystone, medium-gray, noncalcareous, bentonitic. 19 ft 6 in., sandstone, light-olive-gray (grades to light gray with depth) fine-grained (very fine grained near base of core), slightly to very argillaceous, slightly to moderately calcareous. Sand grains are angular to subangular white and clear quartz with gray and dark rock fragments and rare mica. Carbonaceous laminae are abundant in a 2-in. interval 6 in. below the top of the sandstone and in 1-in. intervals at 1,729 and 1,731 ft. A group of oval clay ironstone nodules ½ to 1 in. in diameter is at 1,732 ft and one 2-in. nodule at 1,733 ft. Pale-straw colored cut, very pale-yellow residue in CCl_4 at 1,716 ft; no cut but similar residue at 1,733 ft. At 1,723 ft effective porosity 17.9 percent, air permeability 37 millidarcys, and carbonate content 12.84 percent; at 1,733 ft effective porosity 16.1 percent, air permeability 14 millidarcys, and carbonate content 17.5 percent.
27	1, 735–1, 755	Recovered 12 ft 6 in: Microfossils absent. 5 ft 4 in., sandstone, medium-light-gray, very fine-grained, argillaceous, slightly calcareous in part. At 1,740 ft effective porosity 13.3 percent, air permeability <1 millidarcy.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		2 ft 2 in., clay shale, medium-gray, very slightly micaceous; medium-light-gray laminae of very argillaceous silt. Beds lie flat.
		1 ft 1 in., siltstone, medium-light-gray, very argillaceous, micaceous, noncalcareous.
		7 in., clay shale, as above.
		1 ft 9 in., sandstone, as above; but with abundant crossbedded silt laminae.
		1 ft 7 in., clay shale, interbedded with siltstone.
28	1, 755–1, 775	No recovery.
29	1, 775–1, 776	Recovered 19 ft (including 18 ft from core 28): Microfossils common.
		5 ft 3 in., clay shale, interbedded with siltstone, as in core 27.
		2 ft 7 in., claystone, medium-gray, silty, noncalcareous; grades downward to medium-light-gray slightly calcareous siltstone which grades downward to very fine-grained medium-light-gray calcareous sandstone; the rock types are approximately equal in thickness. A ¼-in. bed of medium-grained sandstone marks the base of the interval.
		3 ft, claystone, medium-dark-gray, very- to slightly silty, micaceous, noncalcareous.
		3 ft 2 in., siltstone, medium-gray, argillaceous, slightly calcareous siltstone interbedded with medium-dark-gray claystone.
		10 in., siltstone, medium-light-gray, slightly sandy, very argillaceous, slightly calcareous; mottled streaks of very calcareous siltstone that resemble swirly bedding.
		4 ft 2 in., claystone, medium-dark-gray, very slightly silty, noncalcareous; laminae of calcareous medium-light-gray siltstone.
----	1, 776–1, 810	Clay shale, medium-dark-gray; trace of siltstone.
----	1, 810–1, 818	Sandstone, fine-grained; coaly intercalations; small amount clay shale and trace of bentonite.
30	1, 818–1, 825	Recovered 7 ft: Microfossils very rare.
		1 ft 9 in., sandstone, light-gray, fine-grained, slightly argillaceous, very calcareous; composed of angular to subangular clear and white quartz with a small amount of gray chert and dark rock fragments. Mica is very rare. Poor shaly cleavage indicates that the beds are approximately flat lying.
		5 ft 3 in., claystone, medium-dark-gray, slightly micaceous, noncalcareous; common laminae of medium-light-gray calcareous siltstone lie essentially flat. Rare ½- to 1-in. clay ironstone beds.
----	1, 825–1, 841	Clay shale, with some light-bluish-gray bentonite, and a small amount of sandstone.
31	1, 841–1, 858	Recovered 17 ft: Microfossils absent.
		2 ft 3 in., sandstone, very light-gray, fine-grained, very calcareous; *Inoceramus* fragments usually less than one-half inch in diameter are abundant.
		6 ft., sandstone, as in core 30; *Inoceramus* fragments (as much as 1½ in. in diameter) abundant in 1½ in. intervals at 1,844 and 1,849 ft, and a 1½-in. bed of yellowish-brown clay with abundant plant impressions and carbonaceous flakes at 1,847 ft. No cut, very pale-yellow residue in CCl_4 at 1,845 ft. At 1,845 ft effective porosity 17 percent, carbonate content 20.85 percent by weight. Grades into unit below.
		8 ft 9 in., sandstone, light-gray, very fine- to fine-grained, argillaceous, calcareous; poor shaly cleavage, and rare slightly crossbedded carbonaceous partings. *Inoceramus* fragments are common in the upper 3 ft. At 1,854 ft effective porosity 13.5 percent, air permeability <1 millidarcy.
32	1, 858–1, 878	Recovered 20 ft: Microfossils absent.
		Sandstone, as in the lower half of core 31 but lacking carbonaceous partings. Fair shaly cleavage indicates that beds are flat lying. Sand grains are angular to subangular, composed of clear and white quartz with some gray and dark rock fragments. Mica is very rare. No cut or residue was noted in CCl_4 at 1,873 ft. At 1,863 ft effective porosity 17.4 percent, at 1,873 ft effective porosity 16.4 percent, and air permeability 17 millidarcys.
33	1, 878–1, 896	Recovered 18 ft: Microfossils very abundant.
		4 ft 6 in., sandstone, medium-light-gray, very fine- to fine-grained, slightly argillaceous, moderately calcareous; composed of angular to subangular grains of clear and white quartz with a minor amount of gray and dark rock fragments. Mica is rare. Poor shaly cleavage indicates that beds lie flat. At 1,880 ft effective porosity 17.9 percent, carbonate content 6.97 percent by weight.
		7 in., claystone, light-olive-gray, noncalcareous.
		2 in., claystone, medium-gray, noncalcareous, very silty.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		7 in., siltstone, medium-light-gray, very argillaceous, noncalcareous, cross-bedded.
		1 in., clay ironstone, yellow-gray, very slightly calcareous.
		½ in., siltstone, as above; with rare rounded black chert pebbles (one-quarter inch in diameter) at base.
		½ in., conglomerate of black chert pebbles, one-eighth to one-quarter inch in diameter; well rounded pebbles with sandy silt matrix.
		6 ft 7 in., clay shale, dark-gray, slightly silty in part, slightly micaceous, noncalcareous; fair shaly cleavage. The top of the Ninuluk and Chandler formations, undifferentiated, at 1,885 ft.
		5 ft 5 in., sandstone, medium-light-gray, very fine- to fine-grained, silty, argillaceous, micaceous, slightly calcareous; a few laminae and partings of clay shale and carbonaceous material. Rare thin (2 in. or less) beds of clay shale.
----	1, 896–1, 897	No sample.
----	1, 897–1, 910	Sandstone, as in cores above; about 5 ft of clay shale.
----	1, 910–1, 915	No sample.
34	1, 915–1, 920	Recovered 5 ft 6 in: Microfossils absent.
		3 ft 5 in., sandstone, fine- to medium-grained, salt and pepper, silty and argillaceous, very calcareous, composed of subangular to subround clear and white quartz grains, and gray and dark rock grains. At 1,916 ft effective porosity 17.5 percent.
		6 in., sandstone interbedded with siltstone and claystone, with a few carbonaceous laminae.
		8 in., clay shale, medium-dark-gray; a few silty micaceous laminae. Very poor shaly cleavage.
		11 in. siltstone, medium- to medium-light-gray, very calcareous; sandy streaks indicates some crossbedding.
35	1, 920–1, 940	Recovered 18 ft: Microfossils very rare.
		7 in., siltstone, slightly sandy, as at base of core 34.
		2 ft 7 in., sandstone, light-gray, fine-grained, very calcareous, massive. Grades into unit below.
		4 ft 10 in., sandstone, medium-gray, medium- to fine-grained, very calcareous; fair shaly cleavage; some carbonaceous partings in upper foot. Beds lie flat. At 1,927 ft effective porosity 13.6 percent, air permeability 1.35 millidarcys, and carbonate content 15.10 percent by weight.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		3 ft 10 in., claystone, medium to medium-dark-gray, slightly to very silty, calcareous. A 1-in. streak of fine-grained sandstone with carbonaceous partings is at 1,929 ft.
		1 ft 2 in., sandstone, light-gray, fine-grained, very calcareous; poor shaly cleavage; scattered carbonaceous partings. A ½-in. section 8 in. below the top of the interval contains abundant disc-shaped rounded fragments of medium-dark-gray shale, 1/16 to 1 in. in diameter; very rare scattered rounded shale fragments are also present in a 6-in. interval below the intraformational conglomerate.
		2 ft 5 in., claystone, as above, silty. Grades into unit below.
		4 in., sandstone, light-gray, very fine-grained, very silty, calcareous; slight cross-bedding.
		5 in., claystone, as above.
		1 ft 10 in., sandstone, as above; grades to fine-grained sandstone. At 1,937 ft effective porosity 11.1 percent, carbonate content 24.8 percent by weight, and rock is impermeable.
36	1, 940–1, 949	Recovered 7 ft: Microfossils very rare.
		2 ft 10 in., claystone, medium-dark-gray, slightly calcareous; with streaks of medium-gray slightly silty clay having swirly bedding. A 4-in. interval of cross-bedded medium-light-gray calcareous siltstone is a foot below the top of the interval.
		2 ft, sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, slightly calcareous; fine crossbedding shown by slightly darker, siltier layers.
		2 ft 2 in., claystone, medium-dark-gray; with abundant lenses and thin irregular discontinuous beds of medium-gray sandy siltstone.
	1, 949–1, 960	Clay shale, with some siltstone.
	1, 960–1, 980	Clay shale, with a small amount of siltstone and sandstone.
	1, 980–1, 990	Clay shale, with bluish-gray bentonite.
	1, 990–2, 000	Clay shale, with a trace of sandstone and bentonite.
	2, 000–2, 020	Siltstone and clay shale, medium-dark-gray, noncalcareous.
37	2, 020–2, 035	Recovered 14 ft: Microfossils absent.
		1 ft 2 in., sandstone, medium-light-gray, fine-grained, very silty, noncalcareous; common carbonaceous partings and laminae showing cross bedding. Grades into unit below.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		3 ft 4 in., claystone, medium-dark-gray, silty, micaceous, noncalcareous. Irregular laminae of sandstone and siltstone are present in the lower two-thirds of the interval.
		5 ft 3 in., sandstone, interlaminated with light- to medium-gray calcareous siltstone and silty clay shale.
		9 in., claystone, medium-dark-gray, slightly silty, noncalcareous; scattered carbonaceous plant fragments.
		1 ft 9 in., claystone, as above; with thin beds and laminae of black shiny coal with shaly cleavage.
		1 ft 9 in., claystone, as above.
	2, 035–2, 056	No sample.
38	2, 056–2, 065	Recovered 9 ft 6 in: Microfossils absent.
		8 ft 8 in., claystone, as at base of core 37; with 1 ft of very silty claystone a foot above the base of the interval.
		10 in., clay shale, black, carbonaceous; coaly laminae.
	2, 065–2, 070	Clay shale, with a small amount of siltstone.
----	2, 070–2, 080	Clay shale.
----	2, 080–2, 100	Clay shale, with some medium-light-gray very fine-grained calcareous sandstone.
----	2, 100–2, 130	Clay shale, with a small amount of siltstone.
----	2, 130–2, 140	Clay shale, with a small amount of sandstone and a trace of siltstone.
----	2, 140–2, 150	Clay shale.
----	2, 150–2, 160	No sample.
----	2, 160–2, 199	Clay shale, sandstone, and siltstone; samples are poor and contain a large amount of recirculated material.
39	2, 199–2, 207	Recovered 8 ft: Microfossils absent.
		5 ft 3 in., sandstone, very light-gray, very fine- to fine-grained, argillaceous, micaceous, slightly calcareous; grades to very fine-grained very silty sandstone at base. Slightly darker, slightly carbonaceous partings are crossbedded. At 2,200 ft effective porosity 3.5 percent, carbonate content 25.8 percent by weight, and rock is impermeable.
		2 ft 9 in., siltstone, medium-light-gray, noncalcareous; medium-gray clay shale laminae increase from absent at top to about two-thirds of the rock at the base of the section.
----	2, 207–2, 220	Sandstone, as in core 39; some clay shale and siltstone, and a minor amount of clay ironstone.
----	2, 220–2, 230	Clay shale, with traces of siltstone and sandstone.
----	2, 230–2, 240	Sandstone, light-gray, fine-grained, noncalcareous.
----	2, 240–2, 250	Sandstone, siltstone, and clay shale.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	2, 250–2, 260	Sandstone, as above; with some siltstone and clay shale.
----	2, 260–2, 270	Siltstone, clay shale, and sandstone.
----	2, 270–2, 280	Sandstone, very fine- to fine-grained, salt and pepper, slightly calcareous in part; a minor amount of clay shale and siltstone. One piece of siltstone has very fine carbonaceous partings.
----	2, 280–2, 330	Clay shale, with siltstone and sandstone.
----	2, 330–2, 340	Sandstone, with some clay shale and siltstone.
40	2, 340–2, 347	Recovered 7 ft: Microfossils rare.
		Claystone, medium-gray, silty in upper part, slightly micaceous, noncalcareous. Fragmental carbonized plant remains are common. Small clay ironstone nodules are abundant at 2,340–2,341 ft. Pelecypod shell fragment at 2,344 ft identified by Ralph W. Imlay as *Lingula* sp.; Roland W. Brown identified a fragment of the plant *Cephalotaxopsis intermedia* Hollick from 2,346 ft.
----	2, 347–2, 360	Clay shale, with some sandstone and trace of siltstone.
----	2, 360–2, 370	No sample.
----	2, 370–2, 390	Clay shale, with fine-grained hard sandstone and siltstone.
----	2, 390–2, 400	No sample.
----	2, 400–2, 410	Clay shale, fine-grained sandstone and siltstone.
----	2, 410–2, 430	No sample.
----	2, 430–2, 440	Clay shale, with fine-grained sandstone, a trace of siltstone, and clay ironstone.
----	2, 440–2, 450	No sample.
----	2, 450–2, 460	Sandstone, fine-grained; with clay shale and a trace of siltstone.
----	2, 460–2, 470	Clay shale, with a minor amount of siltstone, and sandstone.
----	2, 470–2, 480	Siltstone, and clay shale. The top of the Grandstand formation is at 2,475 ft.
----	2, 480–2, 490	Clay shale.
----	2, 490–2, 493	No sample.
41	2, 493–2, 505	Recovered 10 ft: Microfossils abundant.
		2 ft 3 in., clay shale, medium-dark-gray, slightly micaceous, noncalcareous; poor shaly cleavage. A pelecypeod (*Thracia* sp. identified by Ralph W. Imlay) found at 2,494 ft. Beds lie flat. The rock grades into unit below.
		4 ft 8 in., clay shale, medium-gray, interlaminated with medium-light-gray noncalcareous crossbedded silty shale; with a minor amount of sandstone in lower part.
		3 ft 1 in., clay shale, as above; with rare small lenticles of medium-light-gray siltstone.
----	2, 505–2, 510	Sandstone, with some clay shale, and a trace of siltstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	2, 510–2, 530	Clay shale, with a small amount of siltstone.
----	2, 530–2, 540	Clay shale; some sandstone indicated by electric log.
----	2, 540–2, 560	Clay shale, with a small amount of sandstone and siltstone.
----	2, 560–2, 570	Clay shale, sandstone, and siltstone.
----	2, 570–2, 600	Clay shale, with a small amount of sandstone and siltstone.
----	2, 600–2, 610	Clay shale, sandstone, and siltstone.
----	2, 610–2, 620	Clay shale, with a minor amount of sandstone.
----	2, 620–2, 630	Sandstone, with a trace of clay shale. The electric log indicates clay shale for this interval.
----	2, 630–2, 670	Clay shale, with siltstone, and sandstone. Samples are poor, as they contain a large amount of recirculated material.
42	2, 670–2, 683	Recovered 12 ft: Microfossils absent. 5 ft 6 in., sandstone, medium-light-gray, very fine-grained, very argillaceous and silty, slightly calcareous; grades to fine grained at base. The sand is composed of angular to subangular grains of clear quartz with some white quartz and gray and dark rock fragments; mica is rare. Rare beds of claystone ½ to 3 in. thick total less than 10 percent of the rock. Crossbedding, carbonaceous partings, and a few small clay ironstone concretions are present. 6 ft 6 in., claystone, medium-dark-gray, noncalcareous; subconchoidal fracture; poor shaly cleavage; rare silt laminae scattered throughout.
----	2, 683–2, 780	Clay shale, sandstone, and siltstone; samples are poor, as in the interval of rock immediately above core 42.
----	2, 780–2, 820	Clay shale, with a small amount of very fine-grained sandstone in lower 10 ft. Samples are poor through this interval. The electric log indicates a sandstone from 2,800–2,830 ft.
----	2, 820–2, 830	Sandstone, fine-grained.
----	2, 830–2, 840	No sample.
43	2, 840–2, 853	Recovered 12 ft: Microfossils abundant. Claystone, medium-dark-gray, noncalcareous; irregular fracture. Two 1-ft intervals at 2,842 and 2,851 ft contain abundant intercalations of silt and many carbonaceous partings. Light-reddish-brown ironstone concretions are common from 2,842–2,845 ft.
----	2, 853–2, 860	Siltstone, with some sandstone and clay shale.
----	2, 860–2, 880	Clay shale, with sandstone in the upper 10 ft and siltstone in the lower 10 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	2, 880–2, 900	Sandstone, very fine- to fine-grained; some clay shale.
----	2, 900–2, 910	Clay shale, with some siltstone, and a trace of sandstone.
----	2, 910–2, 940	Clay shale, with some sandstone, and a trace of siltstone.
----	2, 940–2, 950	Sandstone, with some clay shale, and a trace of siltstone.
----	2, 950–2, 970	Clay shale, medium-dark-gray, silty; also siltstone and sandstone; one piece of clay shale has a ¼-in. laminae of sandstone.
----	2, 970–3, 020	Sandstone, light-gray, fine-grained, argillaceous, noncalcareous, friable; streaks of clay shale in upper part; very fine-grained noncalcareous harder more argillaceous sandstone in lower 10 ft.
----	3, 020–3, 027	Sandstone, as above, with some clay shale and siltstone.
44	3, 027–3, 047	Recovered 20 ft: Microfossils absent. Sandstone, light-gray, fine-grained, very slightly silty; slightly to moderately calcareous; grains are composed of angular to subangular clear and white quartz, commonly frosted, with rare dark rock grains; mica, pyrite, and glauconite are absent. The sandstone is massive; a few bedding-plane breaks suggest that the beds are flat lying. No oil odor was noticed on fresh breaks; a very pale straw colored cut and a very pale-yellow residue were obtained in CCl_4 from 3,030 ft; a sample from 3,040 ft gave no cut and only a faint greasy stain as residue. A brownish-yellow calcareous clay ironstone nodule at least as large as the diameter of the core, and 1 in. thick is at 3,041 ft; a smaller (¼ x 2 x 1 in.), yellowish-brown noncalcareous nodule at 3,045 ft. The long axes of the nodules are about horizontal; their contacts with the surrounding sandstone are sharp.

Depth [1] (feet)	Effective porosity (percent)	Air permeability (millidarcys)
3,028	11.0	<1.
3,030	12.52	3.58.
3,032	12.7	No plug.
3,034	12.8	7.5.
3,036	13.3	17.6.
3,038	13.3	No plug.
3,040	12.94	1.7.
3,042	15.2	35.0.
3,044	13.6	6.4.
3,046	11.8	1.6.

[1] The content of carbonate minerals at 3,030 ft is 8.95 percent by weight, and at 3,040 ft is 6.04 percent. The other depths were not tested.

Lithologic description—Continued

Core	Depth (feet)	Remarks
45	3, 047–3, 066	Recovered 19 ft: Microfossils absent. Sandstone, as above, with rare scattered small irregular patches of medium-dark-gray clay shale and a few fragments of carbonaceous plant remains. A 3-in. crossbedded interval at 3,057 ft has laminae that dip as much as 27°. A 3-in. bed of medium-gray very calcareous clay shale with intercalations of fine-grained sandstone is at 3,060 ft; it is underlain by a half-inch layer of broken clay shale with the angular fragments separated by small patches of medium-grained sandstone. At 3,066 ft is a 2-in. section of interlaminated medium-light-gray siltstone and medium-dark-gray clay shale, with a few small (½ to 1 in.) lenses of fine-grained very light-gray sandstone. Samples from 3,050 and 3,062 ft showed no cut but gave a very faint greasy stain as residue in CCl_4. At 3,050 ft effective porosity 12.54 percent, air permeability 4.7 millidarcys, and carbonate content 5.39 percent by weight. At 3,062 ft effective porosity 6.22 percent, air permeability 6.75 millidarcys, and carbonate content 8.78 percent.
----	3, 066–3, 087	Sandstone, very fine- to fine-grained; some clay shale, and a trace of siltstone.
46	3, 087–3, 103	Recovered 10 ft: Microfossils absent. Sandstone, very fine- to fine-grained, light- to medium-light-gray, slightly calcareous in part. It is massive and breaks irregularly in spite of a faintly laminated appearance. A sample from 3,090 ft showed no cut and a very faint greasy stain as residue in CCl_4. At 3,090 ft effective porosity 8.68 percent, air permeability <1 millidarcy, and carbonate content 9.76 percent by weight. A mollusk shell fragment at 3,091 ft.
----	3, 103–3, 120	Clay shale and sandstone, very fine-grained; one piece of shale is calcareous. Samples are poor.
----	3, 120–3, 140	Clay shale, silty; with a small amount of siltstone and a trace of sandstone.
----	3, 140–3, 150	Clay shale and sandstone, with a small amount of siltstone.
----	3, 150–3, 180	Clay shale, with a small amount of sandstone, and a trace of siltstone.
----	3, 180–3, 189	Sandstone, medium-light-gray, very fine- to fine-grained; with a minor amount of clay shale.

Lithologic description—Continued

Core	Depth (feet)	Remarks
47	3, 189–3, 205	No recovery. Some of the core from this interval was recovered with core 48.
48	3, 205–3, 211	Recovered 19 ft: Microfossils very abundant. 3 ft, claystone, medium- to medium-dark-gray, slightly to very silty, noncalcareous; irregular intercalations of medium-light-gray siltstone with swirly bedding in the upper 2 ft. 2 ft 2 in., siltstone, medium-gray, sandy, very argillaceous, noncalcareous; with laminae that grade from medium light to medium dark gray with decrease and increase of clay. There is a 2-in. bed of medium-dark-gray claystone at 3,197 ft. 10 in., claystone, interbedded with siltstone, as above. 5 ft, claystone, medium-dark-gray; some streaks and thin (½ in. or less) lenticular beds of medium-light-gray siltstone. Grades into unit below. 3 ft 6 in., claystone, interbedded with siltstone, as above; some siltstone has dark-gray argillaceous carbonaceous partings. 1 ft, siltstone, medium-light-gray, sandy, very argillaceous, noncalcareous, slightly crossbedded, massive. 3 ft 6 in., claystone, as above.
----	3, 211–3, 220	Clay shale, with some siltstone.
----	3, 220–3, 239	Sandstone, and clay shale with a trace of siltstone.
49	3, 239–3, 259	Recovered 20 ft: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous, massive. Sand grains are angular to subangular clear and white quartz, commonly frosted; many are yellowish. Dark rock fragments are rare; mica, pyrite and glauconite are absent. A few crossbedded carbonaceous laminae at 3,240 ft dip 12°; at 3,258 ft a few carbonaceous laminae are flat lying. A few fragments (¼ to ½ in. in diameter) and patches of medium-dark-gray clay shale are present in the sandstone at 3,271 ft. A pale straw-colored cut and a pale-yellow residue in CCl_4 were at 3,240 ft; no cut and very faint greasy stain were recorded at 3,251 ft. At 3,240 ft effective porosity 8.38 percent, and air permeability <1 millidarcy; at 3,251 ft effective porosity 9.68 percent, but the rock is impermeable.

Lithologic description—Continued

Core	Depth (feet)	Remarks
50	3, 259–3, 279	Recovered 20 ft: Microfossils absent. Sandstone, as above; a group of grayish-brown noncalcareous clay ironstone nodules at 3,276 ft are ¼ to 1 in. in diameter, well-rounded, and have sharp contacts with the surrounding sandstone. Samples from 3,263 and 3,277 ft showed no cut and a very faint greasy stain in CCl_4. At 3,263 and 3,277 ft effective porosity 7.9 and 8.8 percent, respectively; both rocks are impermeable.
----	3, 279–3, 290	Sandstone, with clay shale.
----	3, 290–3, 310	Sandstone, medium-light-gray, very fine-grained, argillaceous, noncalcareous; with a minor amount clay shale in the bottom 10 ft.
----	3, 310–3, 320	Clay shale, with a minor amount of sandstone, and a trace of siltstone.
----	3, 320–3, 330	Sandstone and siltstone, with a minor amount of clay shale.
----	3, 330–3, 380	Clay shale and sandstone, medium-gray, very fine-grained, argillaceous, noncalcareous, hard; and siltstone.
----	3, 380–3, 440	Clay shale, very silty in lower part; with a small amount of siltstone.
----	3, 440–3, 450	Clay shale, with a minor amount of siltstone and sandstone, light-gray, very fine- to fine-grained, salt and pepper, noncalcareous.
----	3, 450–3, 460	Clay shale and sandstone, light-gray, very fine-grained, noncalcareous.
----	3, 460–3, 464	No sample.
51	3, 464–3, 482	Recovered 18 ft: Microfossils absent. 2 ft, sandstone, medium-light-gray, fine-grained, argillaceous, very calcareous, massive; composed of clear and white quartz grains that are angular to subangular and commonly frosted; dark rock fragments are rare; mica, pyrite and glauconite are absent. 2 ft, sandstone, as above; but with abundant medium-dark-gray carbonaceous and argillaceous laminae, dipping 5° or less. The sandstone coarsens with depth within this interval. 7 ft, sandstone, as at the top of the core; but slightly calcareous in part. At 3,471 ft effective porosity 7.6 percent air permeability <1 millidarcy, and carbonate content 10.67 percent by weight. Grades into unit below. 7 ft, sandstone, as above, but very fine-grained. At 3,480 ft effective porosity 12.7 percent, rock is impermeable.
52	3, 482–3, 503	Recovered 8 ft: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, argillaceous, silty, noncalcareous, massive. Sand grains are angular to subangular, usually with frosted surfaces, and are composed of clear quartz with some white quartz and dark rock fragments. Mica and pyrite are absent. At 3,487 ft the effective porosity 10.7 percent, and rock is impermeable.
53	3, 503–3, 510	Recovered 20 ft (including 13 ft of core 52): Microfossils absent. 7 ft, sandstone, as in core 52 above; but moderately calcareous. At 3,497 ft effective porosity 8.5 percent, rock is impermeable. 3 ft, sandstone, as above, noncalcareous; with thin (¼ to 2 in.) beds of medium-dark-gray micaceous claystone totaling 10 percent of the section. Some of the faint laminae in the sandstone are slightly crossbedded. 10 ft, sandstone, as in top of core; moderately calcareous in part, massive. At 3,503 ft effective porosity 4.4 percent, rock is impermeable.
54	3, 510–3, 518	Recoverd 8 ft: Microfossils rare. Siltstone, medium-gray, faintly laminated; with a 3-in. section of medium-dark-gray interlaminated siltstone and micaceous clay shale at 3,511 ft and two 3-in. beds of medium-dark-gray non-calcareous claystone at 3,512 ft. The clay-silt contacts are sharp and flat lying. Siltstone grades to medium dark gray, very calcareous toward base of core, with 37.15 percent carbonate content at 3,514 ft.
----	3, 518–3, 528	No sample.
----	3, 528–3, 541	Clay shale, with minor amount of sandstone.
55	3, 541–3, 561	Recovered 20 ft: Microfossils absent. 11 ft 3 in., sandstone, medium-light-gray, very fine-grained, silty, argillaceous, massive; with faint laminae caused by concentration of a small amount of carbonaceous material. Sand grains are similar to those in core 52, but clear or green mica flakes (muscovite and chlorite?) are common. At 3,550 ft effective porosity 9.7 percent, rock is impermeable. 8 ft 9 in., siltstone, as above; but with 5- to 8-in. intervals of interlaminated carbonaceous micaceous partings and medium-light-gray siltstone, and ½- to 4-in. beds of medium-dark-gray clay shale which make up about a quarter of the bed. At 3,557 ft the effective porosity is 8.2 percent, and the rock is impermeable.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	3, 561–3, 590	Sandstone, medium-light-gray, very fine-grained, very silty, argillaceous, noncalcareous; a small amount of clay shale.
----	3, 590–3, 592	No sample.
56	3, 592–3, 602	Recovered 10 ft: Microfossils absent. 5 ft 9 in., siltstone, medium-light-gray, sandy, slightly calcareous in part, massive; 2-in. beds of medium-dark-gray noncalcareous claystone with conchoidal fracture at 3,596 and 3,597 ft. At 3,596 ft the effective porosity 7.3 percent, and rock is impermeable. Pelecypod shell fragment at 3,597 ft was identified by Ralph W. Imlay as *Psilomya*? sp. 1 ft, claystone, medium-dark-gray, interbedded with medium-light-gray siltstone. Beds are ⅛ to 1 in. thick, usually with sharp contacts, some of which resemble broad shallow ripple marks. 1 ft 6 in., siltstone, as above; with a 1-in. claystone bed at 3,599 ft that contains sharp irregular intercalations of siltstone. The lower 5 in. has carbonaceous argillaceous laminae. 1 ft 3 in., claystone and siltstone, interbedded. Contacts are sharp but irregular, and many dip steeply; some fragments of clay shale are rounded and embedded in siltstone to form an intraformational conglomerate. A 1-in. nodule of marcasite is also present. 6 in., claystone, as above.
	3, 602–3, 610	Clay shale, with some sandstone and siltstone.
	3, 610–3, 650	Sandstone, with a trace of siltstone and clay shale; grades downward to clay shale with a trace of siltstone and sandstone. Electric log indicates clay shale in upper part.
	3, 650–3, 670	Clay shale, with a very small amount of sandstone and some siltstone in upper 10 ft. Echinoid spine at 3,660–3,670 ft.
	3, 670–3, 680	Clay shale and siltstone, with a minor amount of sandstone.
	3, 680–3, 690	Clay shale, with a minor amount of sandstone and siltstone; one piece of sandstone is slightly calcareous.
	3, 690–3, 707	Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, slightly calcareous in part; some siltstone and clay shale.
57	3, 707–3, 727	Recovered 17 ft: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, very argillaceous and silty, very slightly micaceous, noncalcareous, massive; composed of angular to subangular clear and white quartz with some dark rock fragments. Mica is rare. The section from 3,712–3,714 ft is slightly darker, and at 3,714 ft there is an irregular 1-in. layer of medium-dark-gray claystone, with scattered fragments of claystone immediately above and below it. Three ft of intercalated sandstone and claystone is similar to the lower part of core 59. At 3,708 and 3,718 ft effective porosity 10.1 and 9.7 percent, respectively; both samples are impermeable.
58	3, 727–3, 742	Recovered 15 ft: Microfossils absent. 8 ft 3 in., sandstone, as above; at 3,730 ft effective porosity 8.9 percent, and rock is impermeable. 7 in., claystone medium-dark-gray, slightly micaceous; scattered specks of carbonaceous material. 4 ft 6 in., sandstone, as above; but with short intervals containing flat-lying or crossbedded laminae. A few disc-shaped pebbles (⅛ to 1 in. in diameter) of medium-dark-gray claystone are 1 ft above the base of this bed. 1 ft 8 in., claystone, medium-dark-gray, very silty, noncalcareous; irregular fracture.
59	3, 742–3, 757	Recovered 15 ft: Microfossils absent. 3 ft 6 in., sandstone, as in core 57; with a 1-in. layer of disk-shaped claystone pebbles 6 in. below top of core. Pelecypod shell fragment at 3,743 ft identified by Ralph W. Imlay as *Entolium* sp. 1 ft 6 in., claystone, medium-dark-gray, noncalcareous, in alternating 5- to 8-in. beds; conchoidal fracture; and sandstone as above. Small lenses and pebbles of claystone are present at top of bed. 5 ft, sandstone, as above; with a 10-in. interval containing scattered intercalations of claystone at 3,747–3,748 ft and 7 in. of intercalated thin (approximately one-quarter inch) irregular beds of claystone and sandstone at 3,749 ft. 4 ft, claystone, medium-dark-gray, intercalated with medium-light-gray sandstone. The beds are ⅛ to 2 in thick; contacts are sharp and irregular. 6 in., sandstone, as above.

Lithologic description—Continued

Core	Depth (feet)	Remarks
60	3,757–3,769	Recovered 12 ft: Microfossils absent. 2 ft 10 in., sandstone, very fine-grained, as in core 57; but with carbonaceous partings giving good shaly cleavage and a slight laminated appearance in lower part. Dip of laminae 5° or less. Three- to five-in. intervals of claystone total about one-fourth of the rock. 1 ft 2 in., claystone, medium-dark-gray; intercalations of medium-gray siltstone totalling one-third of the section. 10 in., claystone, medium-dark-gray, grades downward to medium-gray siltstone with faint slightly carbonaceous laminae. Grades into unit below. 7 ft 2 in., sandstone, as at top of core; with rare thin irregular layers of claystone. Three-inch beds of claystone are at 3,767 and 3,769 ft. Pelecypod shell fragment at 3,765 ft.
	3,769–3,800	Sandstone, as in core above; but with rare pyrite and mica.
	3,800–3,820	Sandstone, as above, and clay shale.
	3,820–3,825	No sample.
61	3,825–3,845	Recovered 20 ft: Microfossils abundant. 6 ft 3 in., clay shale, medium-dark gray, micaceous and silty, noncacareous; thin beds and irregula-laminae (1/16 to 2 in. thick) of mediumr light-gray noncalcareous siltstone totaling 10 percent of the rock. Poor shaly cleavage indicates beds lie flat. 13 ft 9 in., sandstone, medium-light-gray, very fine-grained, silty, argillaceous, slightly calcareous in part, massive. A 4-in. bed of medium-dark-gray claystone at 3,836 ft is underlain by a 10-in. section of fine-grained sandstone. At the base of this is a parting marked by a single layer of 1/8 to 3/4 in. of light and dark chert pebbles. There are a few small (1/4 to 1/2 in.) discs of medium-dark-gray claystone marking 2 or 3 flat bedding planes in a 2-inch interval at 3,840 ft. At 3,833 ft effective porosity 8.6 percent, and rock is impermeable.
62	3,845–3,862	Recovered 17 ft: Microfossils rare. 11 ft, sandstone, as above; fragments very calcareous in upper 3 ft, slightly calcareous below. At 3,849 and 3,856 ft effective porosity 8.9 and 9.6 percent, respectively; both samples are impermeable. Carbonate content about 8 percent by weight in the higher sample.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		6 ft, sandstone, as above, very silty; but with abundant intercalations and scattered thin beds of medium-dark-gray claystone which total one-third of the rock. Clay-sand contacts are sharp and some resemble ripple marks. A few slightly carbonaceous micaceous laminae are present near base of core, dip 3° or less. Sand grains are angular to subangular, composed of white and clear quartz and abundant dark rock fragments. Glauconite and pyrite are absent. *Ditrupa* sp. fragments.
63	3,862–3,882	Recovered 19 ft: Microfossils absent. 3 ft, sandstone, with beds and intercalations of clay shale as above. 16 ft, sandstone, as in core 61, very slightly calcareous in part. Fluorescence with a very pale-straw-colored cut, and yellow residue in CCl_4 were noted at 3,870 and 3,872 ft. A 15-in. bed of medium-dark-gray noncalcareous slightly silty and micaceous claystone at 3,872–3,873 ft. At 3,866 and 3,876 ft effective porosity 9.9 and 9.5 percent; both samples are impermeable.
64	3,882–3,898	Recovered 15 ft 6 in.: Microfossils rare. Sandstone, as in core 61; with 3-in. claystone beds at 3,884, 3,887, and 3,889 ft. Interbedded sandstone and dark-gray clay shale occupy a 6-in. section at 3,883 ft and 10-in. sections at 3,888, 3,892, and 3,893 ft. One-foot sections of the sandstone at 3,884 and 3,894 ft are faintly to finely laminated with carbonaceous and micaceous partings. The upper bed shows slight cross-bedding; the lower one, which is very evenly laminated, has a dip of 1°. At 3,884 and 3,894 ft effective porosity 7.2 and 2.5 percent, respectively; both samples are impermeable.
65	3,898–3,910	Recovered 10 ft: Microfossils very rare. 7 ft, sandstone and claystone. The upper 7 ft of this core was disturbed before reaching the laboratory; the rock consists of medium- to medium-light-gray very fine-grained very silty argillaceous sandstone with laminae and thin beds (as much as 6 in. thick) of medium-dark-gray claystone, slightly to very silty in part, totaling about 15 percent of the rock. 3 ft, siltstone, medium- to medium-light-gray, very argillaceous, noncalcareous; scattered carbonaceous and micaceous partings; thin (1/4 to 1 in.) beds of medium-dark-gray clay.

Lithologic description—Continued

Core	Depth (feet)	Remarks
66	3, 910–3, 918	Recovered 7 ft: Microfossils rare. Claystone, medium-dark-gray, very silty and micaceous, noncalcareous; with ½- to 3-in. beds of medium-gray siltstone totaling 20 percent of the rock.
	3, 918–3, 928	No sample.
	3, 928–3, 978	Clay shale, with sandstone and siltstone as in cores above.
67	3, 978–3, 987	Recovered 9 ft: Microfossils abundant. Claystone, medium- to medium-dark-gray, very silty, noncalcareous; rare streaks and patches of sandy argillaceous noncalcareous siltstone and sandstone.

CORE ANALYSES

Samples from sandstones cored in Square Lake test well 1 were tested for effective porosity by the Barnes method, and for air permeability on a permeameter, the general requirements for which are detailed in American Petroleum Institute's code No. 27, second edition, April, 1952. The content of carbonate minerals was also determined, and the results of these tests are presented in the following table.

Analyses of core samples from Square Lake test well 1

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)	Carbonate content (percent by weight)
237	15. 5	0	29.1.
247	12. 4	0	Trace.
514	15. 1	0	Trace.
525	9. 4	0	17.9.
576	14. 3	9	10.25.
611	21. 8	54	Trace.
627	1. 9	0	40.8
632	23. 2	11	Trace.
641	10. 9	0	25.6.
661	18. 2	0	Trace.
672	17. 3	0	Trace.
683	11. 7	0	Trace.
1, 063	15. 4	12	10. 7.
1, 067	1. 6	0	47.1.
1, 646	18. 7	20	13.73.
1, 662	11. 6	0	15.68.
1, 671	10. 3	<1	13.45.
1, 685	18. 3	28	5.85.
1, 687	20. 4	30	Trace.
1, 699	18. 8	43	Trace.
1, 706	20. 2	<1	Trace.
1, 723	17. 9	37	12.84.
1, 733	16. 1	14	17.5.
1, 740	13. 3	<1	Trace.
1, 845	17. 0	No plug	20.85.
1, 854	13. 5	<1	Trace.
1, 863	17. 4	No plug	Trace.
1, 873	16. 4	17	Trace.
1, 880	17. 9	No plug	6.97.
1, 916	17. 5	645 (cracked)	Trace.
1, 927	13. 6	1.35	15.10.
1, 937	11. 1	0	24.8.
2, 200	3. 5	0	25.8.
3, 028	11. 0	<1	Not tested.
3, 030	12. 52	3.38	8.95.
3, 032	12. 7	No plug	Not tested.
3, 034	12. 8	7.5	Not tested.
3, 036	13. 3	17.6	Not tested.
3, 038	13. 3	No plug	Not tested.
3, 040	12. 94	1.7	6.04.
3, 042	15. 2	35.0	Not tested.
3, 044	13. 6	6.4	Not tested.
3, 046	11. 8	1.6	Not tested.
3, 050	12. 54	4.7	5.39.
3, 062	6. 22	6.75	8.78.
3, 090	8. 68	<1	9.76.
3, 240	8. 38	<1	Trace.
3, 251	9. 68	0	Trace.
3, 263	7. 9	0	Trace.
3, 277	8. 8	0	Trace.
3, 471	7. 6	<1	10.67.
3, 480	12. 7	0	Trace.
3, 487	10. 7	0	Trace.
3, 497	8. 5	0	Trace.
3, 503	4. 4	0	Trace.
3, 514			37.15.
3, 550	9. 7	0	Trace.
3, 557	8. 2	0	Trace.
3, 596	7. 3	0	Trace.
3, 708	10. 1	0	Trace.
3, 718	9. 7	0	Trace.
3, 730	8. 9	0	Trace.
3, 833	8. 6	0	Trace.
3, 849	8. 9	0	About 8.
3, 856	9. 6	0	Trace.
3, 866	9. 9	0	Trace.
3, 876	9. 5	0	Trace.
3, 884	7. 2	0	Trace.
3, 894	2. 5	0	Trace.

HEAVY-MINERAL ANALYSIS

Heavy-mineral samples prepared in the Fairbanks laboratory were analyzed by Robert H. Morris of the Geological Survey, who prepared the heavy-mineral chart (fig. 35). Sandstone samples were disaggregated and treated with dilute hydrochloric acid to remove the carbonates. The disaggregate was sieved, and the material passing the 80-mesh and retained on the 235-mesh screen was separated in bromoform (sp. gr. 2.7) and methylene iodide (sp. gr. 3.0) into light, medium, and heavy fractions. Slides of the heavy fractions (sp.

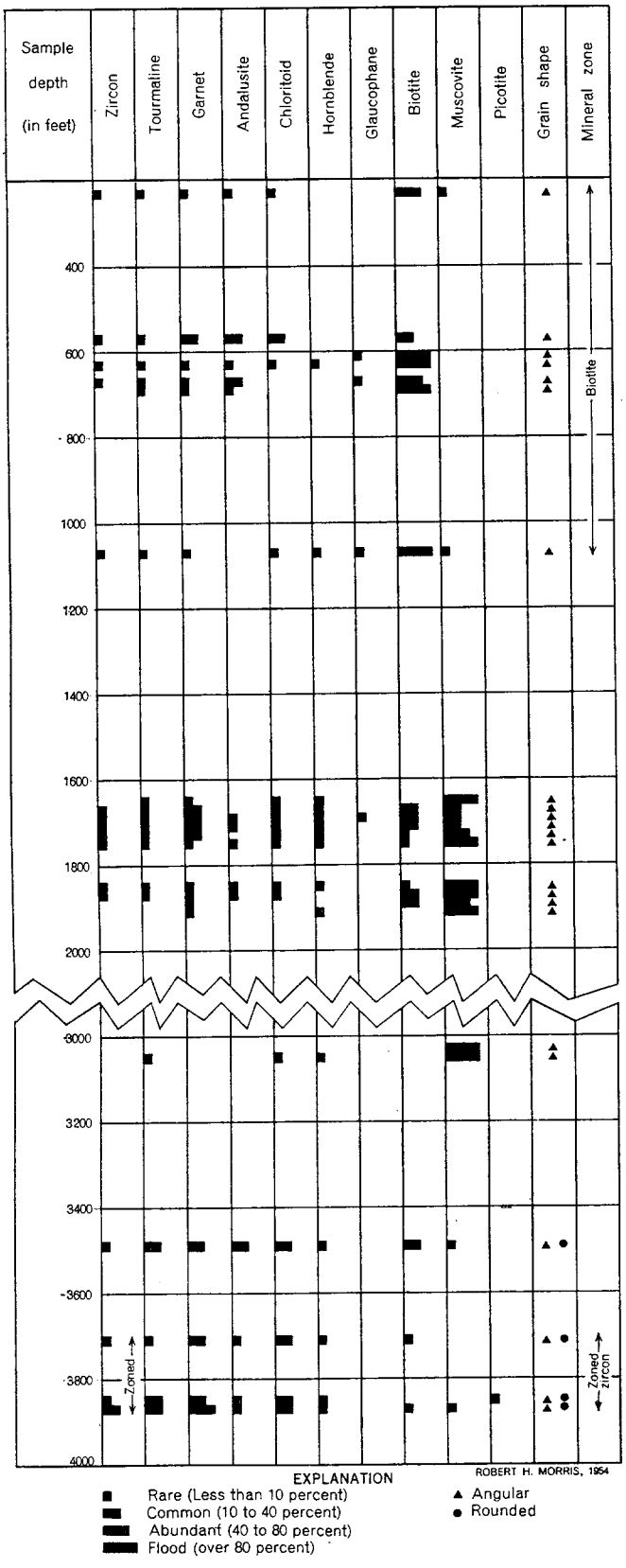


FIGURE 35.—Relative abundance of heavy minerals in Square Lake test well 1.

gr. 30 or greater) were prepared with canada balsam or aroclor. Two heavy-mineral zones are recognized in Square Lake test well 1: the biotite zone, in several samples between 220 and 1,080 feet; and the zoned-zircon zone, from 3,700 to 3,880 feet. Samples between 1,640–3,060 feet contain an abundance of muscovite.

OIL AND GAS

OIL AND GAS SHOWS

No commercial shows of oil were found in Square Lake test well 1, but some gas was produced from sandstone beds between 1,600 and 1,900 feet (see formation tests 4 and 5, below). Core samples were tested for oil cuts. The cores were tested in the Fairbanks laboratory 1 to several days after the cores were taken, depending on the availability of transportation from Umiat to Fairbanks. The sandstone was crushed to approximately single-grain particles, carbon tetrachloride was added, and the mixture shaken. Any color appearing in the carbon tetrachloride after settling and filtering was described as the cut; the residue is any material left in the evaporating dish after the carbon tetrachloride has been allowed to evaporate. The consistency of the residue varied from a greasy film to an oily liquid. The results of the tests are given in the following table.

Core samples from Square Lake test 1 tested for oil stain in carbon tetrachloride

Depth	Cut	Residue
1,662	Pale straw colored	Very pale yellow.
1,702	do	Do.
1,716	do	Do.
1,733	None	Do.
1,845	do	Do.
1,873	do	None.
3,030	Very pale straw colored	Very pale yellow.
3,040	None	None.
3,050	do	Very faint greasy stain.
3,062	do	Do.
3,090	do	Do.
3,240	Pale straw colored	Pale yellow.
3,251	None	Very faint greasy stain.
3,263	do	Do.
3,277	do	Do.
3,487	do	Pale yellow.
3,497	do	Do.
3,503	do	Do.
3,550	do	Do.
3,557	do	Do.
3,755	do	Do.
3,870	Very pale straw colored	Yellow.
3,872	do	Do.

Arctic Contractors' well geologist, Robert D. Rutledge, also noted a fleeting odor and a very pale cut in sandstone beds at 3,464–3,510 feet and 3,831–3,898 feet.

FORMATION TESTS

Twelve formation tests with the Johnston formation tester were attempted in Square Lake test well 1. The first 3 tests, and the sixth, were unsuccessful; 2 tests resulted in moderate to strong blows of gas, and the others recovered water and drilling mud. In each case the hole was open from the packer to the current total depth. A description of the tests follows:

Test 1, 1,642–1675 feet.—A 6¾-inch packer was set in a 7½-inch hole at 1,642 feet; but the trip valve was released while installing the tools, and the test was unsuccessful.

Test 2, 1,642-1,675 feet.—A 6¾-inch packer was set at 1,642 feet, but it failed to hold.

Test 3, 1,646–1,675 feet.—A 6¾-inch packer was set at 1,646 feet, but it failed to hold after 5 minutes.

Test 4, 1,646–1,675 feet.—The hole was reamed to 1,675 feet, and an 8⅝-inch packer was set at 1,646 feet, with 29 feet of tailpipe including 17 feet of perforated pipe. A 5/16-inch bean in the tester was open 1 hour and 46 minutes, and then was closed for 20 minutes. After 45 minutes of moderate blow, a critical flow prover indicated a gas flow of 112,000 cubic feet per day. The test was not reliable, however, because ice formed in the orifice. After gas flowed for 54 minutes, the hole began producing water by heads. Salinity of the mud was 660 parts per million, and that of the recovered fluid was 8,745 parts per million. The bottom-hole flowing pressure was 425 psi.

Test 5, 1,847–1,879 feet.—A 7¼-inch packer was set at 1,847 feet, with 32 feet of tailpipe, of which 17 feet was perforated. A 5/16-in. bean in the tester was open 1 hour and 10 minutes, and the packer pulled loose from the seat 13 minutes later. The tester produced a strong blow of gas for 30 minutes and then produced water and mud through the annulus. The salinity of the drilling fluid was 607 parts per million and that of the recovered fluid was 3,135 parts per million. The bottom-hole flowing pressure was 500 psi, and the bottom-hole static pressure was 800 psi. A critical flow prover test was unsuccessful because ice formed on the orifice of the instrument.

Test 6, 1,878–1,897 feet.—A 7¼-inch packer was set at 1,878 feet, with 19 feet of tailpipe (including 5 feet of perforated pipe). The test was unsuccessful because the retaining valve did not open.

Test 7, 1,878–1,897 feet.—A 7¼-inch packer was set at 1,878 feet, with 5 feet of perforated pipe included in the 19 feet of tailpipe. A ⅜-inch bean was open 1 hour and closed for 10 minutes. No gas came to the surface, and 90 feet of water-cut drilling mud was recovered. The salinity of the mud was 623 parts per million, and the fluid that was recovered had a salinity of 2,970 parts per million. The bottom-hole pressure was 200 psi.

Test 8, 3,033–3,067 feet.—A 7¼-inch packer was set at 3,033 feet, with 34 feet of tailpipe, of which 23 feet was perforated. A ⅜-inch bean in the tester was open 90 minutes; no gas came to the surface. After being closed in for 10 minutes, the bottom-hole flowing pressure built up to 375 psi, and the static bottom-hole pressure was 400 psi. The test recovered 780 feet of water. Salinity of the drilling fluid was 528 parts per million, and that of the recovered fluid was 330 parts per million.

Test 9, 3,466–3,482 feet.—A 7¼-inch sidewall packer was set at 3,466 feet, with 16 feet of tailpipe, including 10 feet of perforated pipe. The tester was open 1 hour and 53 minutes and closed for 15 minutes. Fifty feet of drilling fluid was recovered which had a salinity of 387 parts per million. The bottom-hole flow pressure and the bottom-hole shut-in pressure were both indicated by the pressure recorder to be zero.

Test 10, 3,714–3,742 feet.—A 7½-inch packer was set at 3,714 feet with 18 feet of perforated and 10 feet of unperforated tailpipe. The ⅜-inch bean in the tester was open 1 hour and 51 minutes, and closed for 15 minutes. Both flowing and bottom-hole pressure were zero. No gas came to the surface; 8 feet of drilling mud with a salinity of 950 parts per million were recovered.

Test 11, 3,833½–3,845 feet.—A 7¼-inch packer was set at 3,833½ feet, with 11.6 feet of tailpipe, including 6 feet of perforated pipe. The ⅜-inch bean in the tester was open 93 minutes, but no gas came to the surface and the bottom-hole pressure was zero. Ten feet of drilling fluid was recovered. Its salinity, 2,240 parts per million, was raised by the presence of pyrophosphate in the drilling mud.

Test 12, 3,850–3,882 feet.—A 7¼-inch packer was set at 3,850 feet, with 32.5 feet of tailpipe, 24 feet of which was perforated. A ⅜-inch bean in the tester was open 104 minutes and closed 15 minutes. The bottom-hole pressure was zero. The test recovered 100 feet of drilling fluid (salinity 990 parts per million), which had entered the tool while it was being lowered into place.

GAS AND WATER ANALYSES

Samples of gas from formation tests 4 and 5 were submitted to the U. S. Bureau of Mines for analysis. The gas in each sample was found to be badly contaminated with air, and the analyses are therefore not presented here. A sample from formation test 5 (1,847–

466290—59——4

1,879 feet), was sent to the National Bureau of Standards and analyzed by S. Schumann as follows:

Component	Mol percent	Component	Mol percent
Helium	None	Oxygen	None
Methane	99.3	Carbon dioxide	.11
Nitrogen	.40	Propane	None
Ethane	.16	Butane	None

Water samples from formation tests 4, 5, and 8 were also submitted to the U. S. Bureau of Mines. Analyses of samples from tests 4 and 8 are presented in the following table. The sample from test 5 was largely drilling mud; and the small amount of water separated from the mud had a chloride content of 1,600 parts per million (equivalent to 2,600 parts per million of NaCl), and a specific gravity of 1.001. It was not analyzed further.

Analysis of water from formation tests 4 and 8 in Square Lake test well 1

[Analyses by the U. S. Bur. Mines]

Radical	Parts per million	
	Test 4 (1,646-1,675 feet)	Test 8 (3,033-3,067 feet)
Calcium	34	12
Magnesium	36	6
Sodium	2, 960	1, 020
Carbonate	64	51
Bicarbonate	1, 260	2, 400
Sulfate	29	23
Chloride	3, 900	140
Total solids	8, 283	3, 652
H_2S detected	None	None
Specific gravity at 15.6° C	1. 005	1. 001

LOGISTICS

About 1,350 tons of supplies and equipment (including the Cardwell drilling rig from Titaluk test well 1) to drill Square Lake test well 1 were hauled to the site on sleds by 3 tractor trains in late 1951 and in the spring of 1952. Personnel was flown in by bush planes which landed on the nearby lake using skis in winter and floats in summer.

Information in this paper about personnel, equipment, and supplies has been compiled from data recorded on the test well by Arctic Contractors.

Personnel.—The supervisory staff consisted of 1 drilling foreman, 1 petroleum engineer, and 1 geologist in charge of drilling the test. The rig crew consisted of 2 drillers, 2 derrickmen, 2 floormen, 2 firemen, 2 heavy-duty-equipment mechanics, and 1 oiler and small-crane operator. Other men permanently employed were 2 cooks, 2 cook's helpers, 2 crane operators, and 1 man who served as warehouseman and storekeeper. Others, such as carpenters, laborers, 1 welder, 1 radio repairman, 1 electrician, 1 cement and formation-test technician, and 1 Schlumberger engineer were sent from Barrow or Umiat as their services were needed.

Housing.—Twelve wanigans (small one-room buildings mounted on skids or runners to facilitate moving) and eight jamesway huts (jamesway huts, which are similar in shape to quonsets, are made of canvas over a metal frame, and are usually slightly smaller) were used for shelter. The wanigans housed the boiler, the geologist's office, the shop, the Schlumberger equipment, the generator, the cement pump and motor, the lavatory, and cement, water, food, and miscellaneous storage; one was used as a utility room. Five of the jamesway huts were used for sleeping, 1 for a kitchen, 1 for eating, and 1 was both a dormitory and a store.

Vehicles and heavy equipment.—The camp at Square Lake test well 1 was equipped with 2 weasels (military vehicles, fully-tracked), 1 D8 Caterpillar tractor, 1 TD–9 International tractor with crane (cherrypicker), and 1 swing crane. One of each of the following major items of drilling equipment was used by Arctic Contractors:

Ideco standard derrick, 87 ft high with 24-ft base (mounted on runners from an Athey sled).
120-ton Ideal type D–12 crown block with five 34-in. sheaves grooved for 1 in line.
120-ton Ideal type D–12 traveling block with four 34-in. sheaves grooved for 1-in. line.
125-ton Byron Jackson type 4125 Triplex hook with bail
Ideal type FE 17½-in. rotary table.
150-ton Ideal type D swivel.
Cardwell model H drawworks, skid mounted, complete with cat heads and rotary-drive assembly.
Caterpillar diesel engine model D8800 on drawworks.
Ideal type C-250 power duplex slush pump, 7¼ by 15 in.
General Motors quad diesel engine, model 24103, series 671 on slush pump.
Shaffer double gate blowout preventer.
60-bbl. divided mud tank.
35 hp. Kewanee boiler.
Halliburton cementing unit.
Schlumberger automatic recorder and deep winch.

Fuel, lubricant, and water consumption.—About 83,600 gallons of diesel fuel and 2,030 gallons of 72-octane gasoline were burned to furnish power for drilling the test; lubrication required 456 gallons of lubricating oil, and 420 pounds of thread-lubricating grease. Water used in mixing mud and for other purposes totaled 554,200 gallons.

DRILLING OPERATIONS

DRILLING NOTES

Information presented in this section was reported by Everette Skarda, petroleum engineer for Arctic Contractors.

Notes from drilling records

Depth (feet)	Remarks
21	Bottom of cellar.
110	Cemented 4 joints of 13⅜-in. 54.5-lb range 2 grade J–55 seamless casing at 110 ft with 85 sacks of Cal-Seal.
713	While reaming the hole at 713 ft, mud was lost at a rate of 30 bbl per hr. The addition of Jelflake and Fibertex did not stop the loss, which was then traced to a washout behind the casing. The washout may have been caused by heat from the drilling mud which thawed permafrost behind the casing cement. The casing was recemented with 35 sacks of Cal-Seal and 10 sacks of High-Early cement.
728	Cemented 728 ft of 10¾-in. 55.5-lb Hydril streamlined casing with 160 sacks of High-Early cement. Installed blowout preventers.
1,087	A sledge hammer dropped in the hole was recovered with a Globe basket.
3,987	Four cement plugs were set in the hole through open-end drill pipe to seal off the gas-bearing sandstones and to protect them from contamination by water-bearing beds. For the first one, 80 sacks of High-Early cement were displaced at 2,935 ft, with the top of the plug at 2,745 ft. The next two were set between 1,865 and 1,934 ft, and from 1,640 to 1,840 ft. The top plug, at 700–741 ft, was set through the lower end of the casing. The hole was then bailed down to 225 ft, the blowout preventers removed, and a 10¾-in. nipple welded to the top of the casing, 1¾ ft above the ground.

DRILL AND CORE BITS

Reed conventional Kor-King bits were used to core 1,043 feet of hole. Of the bits used, 10 were type K–25, soft-formation bits, and the rest were type K–24, hard-formation bits. The first 6 bits were 6¼ inches in diameter, but the others, except 2 used near the bottom of the hole, were 7½-inch bits. About 92 percent of the rock cored was recovered.

Drill bits ranged in size from a 17½-inch Security hole opener to a 9⅝-inch Hughes OSC–3 rock bit. The latter was the most common type of bit used, but a few Smith DDT and Reed type 2 and 2C rock bits were also used. On the graphic log (pl. 29) drill bits that alternately reamed and drilled short intervals are shown only as having drilled these intervals.

DRILLING MUD

Desirable characteristics were maintained in the water-base mud used for drilling Square Lake test well 1 by the use of Aquagel, Quebracho, and Baroid, with a small amount of tetrasodium pyrophosphate and caustic soda. At 713 feet 4 sacks of Jelflake, 2 sacks of Fibertex, and 23 sacks of Aquagel were added to the mud because of loss of circulation, before the mud loss was traced to a washout behind the casing. At 2,779 feet, 50 barrels of new mud were mixed because some had been lost when the plug was dislodged from the mud pits. The following table presents the characteristics and additives of the drilling mud used in drilling the test.

Drilling-mud characteristics and additives, Square Lake test well 1

Depth	Weight (lb per cu ft)	Viscosity (Marsh funnel sec)	Water loss (cc per 30 min)	Temperature (° F)	Aquagel (sacks)	Quebracho (lb)	Pyrophosphates (lb)	Other additives
110	67	34	-------	70	18	-------	-------	
268	75	35	10.5	80	2	25	25	
462	74	46	8.7	65	11	100	50	
590	70	37	6.5	58	-------	-------	-------	
669	73	40	7.2	54	7	50	-------	
713	-------	-------	-------	-------	23	-------	-------	4 sacks Jelflake, 2 sacks Fibertex.
728	74	46	6.9	54	28	25	500	
750	85	67	5.8	71	-------	-------	-------	150 sacks Baroid.
1,065	84	54	5.8	77	-------	-------	-------	5 lb caustic soda.
1,077	82	50	6.3	65	4	-------	-------	15 sacks Baroid.
1,175	-------	-------	-------	-------	-------	25	-------	
1,200	85	54	6.3	73	-------	-------	-------	
1,312	85	54	5.6	75	-------	50	-------	
1,435	85	58	5.0	75	-------	-------	-------	
1,500	85	54	5.0	72	-------	-------	-------	
1,610	85	55	5.0	75	-------	50	-------	
1,675	86	60	5.0	64	-------	110	20	5 lb sodium bicarbonate.
1,714	86	52	5.3	54	-------	-------	-------	48 sacks Baroid.
1,780	86	54	5.0	60	-------	-------	-------	
1,830	86	54	5.3	64	-------	-------	-------	
1,880	87	54	5.0	63	-------	-------	-------	
1,900	86	54	5.0	60	-------	-------	-------	
1,925	86	55	5.0	58	-------	-------	-------	
1,980	86	56	5.3	68	-------	-------	-------	
2,050	86	55	5.3	67	½	25	-------	15 lb sodium bicarbonate.
2,120	86	54	6.0	76	-------	-------	-------	
2,200	86	55	6.0	76	-------	-------	-------	
2,295	87	55	5.6	78	-------	-------	-------	
2,383	86	57	5.6	73	-------	50	-------	
2,493	87	55	5.6	78	-------	50	20	
2,585	87	53	5.2	79	-------	-------	-------	
2,627	88	54	5.3	79	-------	25	15	
2,670	89	54	5.5	76	-------	75	20	
2,741	87	56	5.3	72	-------	50	-------	
2,779	-------	-------	-------	-------	-------	100	20	72 sacks Baroid.
2,808	91	55	4.8	75	-------	-------	-------	
2,850	92	54	4.8	68	-------	-------	-------	
2,928	92	55	5.0	64	-------	-------	-------	
2,995	92	54	4.8	75	¾	100	20	10 lb caustic soda.
3,050	92	53	4.6	70	-------	-------	-------	
3,068	92	54	5.0	65	-------	-------	-------	
3,100	91	55	5.0	70	-------	-------	-------	
3,192	91	56	4.8	75	-------	-------	-------	
3,210	91	57	4.8	64	-------	-------	-------	
3,250	91	56	4.6	65	-------	-------	-------	
3,276	91	56	4.4	63	-------	355	40	35 lb caustic soda.
3,340	91	54	4.3	64	-------	-------	-------	
3,368	91	55	4.5	68	-------	-------	-------	
3,395	91	53	4.1	66	-------	-------	-------	
3,450	91	52	4.3	74	-------	-------	-------	
3,507	91	54	4.3	74	-------	-------	-------	
3,515	91	52	4.6	64	-------	125	20	100 lb Aeroseal.
3,580	91	55	4.5	70	-------	-------	-------	
3,602	91	52	4.4	70	-------	-------	-------	
3,640	92	55	4.3	70	-------	-------	-------	
3,682	92	53	4.3	73	-------	-------	-------	
3,713	93	58	4.4	74	-------	-------	-------	
3,740	92	50	4.2	73	-------	-------	55	375 lb Aeroseal.
3,755	91	50	4.1	68	-------	-------	-------	40 lb caustic soda.

Drilling-mud characteristics and additives, Square Lake test well 1—Continued

Depth	Weight (lb per cu ft)	Viscosity (Marsh funnel sec)	Water loss (cc per 30 min)	Temperature (° F)	Aquagel (sacks)	Quebracho (lb)	Pyrophosphates (lb)	Other additives
3,775	91	50	4.2	70	------	------	------	
3,825	93	58	4.4	75	------	------	------	
3,845	91	50	5.0	72	------	------	------	
3,860	91	51	4.8	64	------	------	------	
3,882	91	49	4.8	64	------	------	------	
3,910	91	57	5.0	65	------	325	190	100 lb Driscose, 15 lb caustic soda, 10 sacks Baroid.
3,923	91	55	4.0	65	------	------	------	
3,960	92	60	4.0	68	------	------	------	
3,987	91	54	4.0	66	------	------	------	

HOLE DEVIATION

Deviation from vertical in Square Lake test well 1 ranged from 0°15′ to 2°00′ and averaged approximately 0°50′. The greatest deviation occurred between 1,700–2,100 feet; above and below that interval the hole was rarely as much as 1° from vertical. Deviation measurements were made with a Totco (Techanical Oil Tool Corp., Ltd.) recorder and are shown on the graphic log (pl. 29).

ELECTRIC LOGGING

Electric logs were made in several runs between 110 and 3,984 feet by Schlumberger Well Surveying Corp. Runs 5 and 6 duplicated part of the earlier runs, in order to record the curves on different scales. On the graphic log (pl. 29), run 6 is used in place of runs 2–5. The depths recorded in each run are given below:

Run	*Depth (feet)*	*Run*	*Depth (feet)*
1	110–728	5	1,500–3,389
2	728–1,675	6	728–3,752
3	1,675–2,664	7	3,750–3,875
4	2,664–3,062	8	3,875–3,984

WOLF CREEK AREA

In 1951 and 1952 Arctic Contractors drilled three holes to test the oil-producing possibilities of the Wolf Creek anticline, a structural feature with a northwestward trend about parallel to the other anticlines in the northern foothills section of the Arctic foothills province.

The northern foothills section of the province in the vicinity of the Wolf Creek tests has a maximum relief of about 1,000 feet. Northwestward-trending escarpments parallel the Wolf Creek anticline to the north and south, although the anticline follows a lower less rugged ridge. There is about a 250-foot difference in the elevation between Wolf Creek test wells 1 and 3 on the crest and Wolf Creek test well 2 in the creek valley on the north flank.

Wolf Creek anticline, first mapped by a Geological Survey field party in 1946, was studied in more detail in 1947. It was further defined in 1949 by photogeologic mapping by William P. Brosgé who also drew the structure-contour map of the area shown in figure 36. This narrow anticline is about 30 miles long, and a possible western extension may add another 25 miles to its length. Two hundred feet of proven closure encompasses an area 5 miles long, near the east end of the anticline; maximum closure of 600 feet, enclosing an area 16 miles long, is possible but cannot be proved (Brosgé, written communication, 1956).

The 3 wells were drilled in Cretaceous rocks: Wolf Creek test wells 1 and 3, 485 feet apart on the crest of the anticline, penetrated rocks of the Nanushuk group (Lower and Upper Cretaceous): Wolf Creek test well 2, a mile and a third away down the north flank, drilled through 130 feet of the Seabee formation (Colville group, Upper Cretaceous) before entering older beds.

Wolf Creek test wells 1 and 3 found a small amount of gas which has no present commercial value. The highest rate of flow, measured in Wolf Creek test well 1, was 1,304,900 cubic feet per day at 8 pounds pressure through a 1½-inch orifice, with shut-in pressure building up to 60 pounds in 30 minutes. Wolf Creek test well 2 had only a faint show of gas and produced some salty water.

STRATIGRAPHY

A small amount of alluvium, which mantles the Cretaceous rocks, was drilled in Wolf Creek test wells 1 and 2; in the latter test, located near a small creek, the drillers reported penetrating gravel, underlain by olive-gray clay, before reaching Cretaceous rocks 40 feet below the derrick floor.

SEABEE FORMATION

Ninety feet of the Seabee formation (Colville group, Upper Cretaceous) overlie rocks of the Nanushuk group (Lower and Upper Cretaceous) in Wolf Creek test well 2. These beds consist of olive- and medium-gray siltstone, with a small amount of gray sandstone and clay shale, some clay ironstone, and a small amount of light-yellowish-gray bentonite containing abundant euhedral biotite flakes.

NINULUK FORMATION

Beds of the marine Ninuluk formation (Upper Cretaceous), uppermost part of the Nanushuk group, are the youngest Cretaceous rocks found in Wolf Creek test wells 1 and 3; the following description is based primarily on information from those wells. In these wells the Ninuluk formation consists of 200 feet of

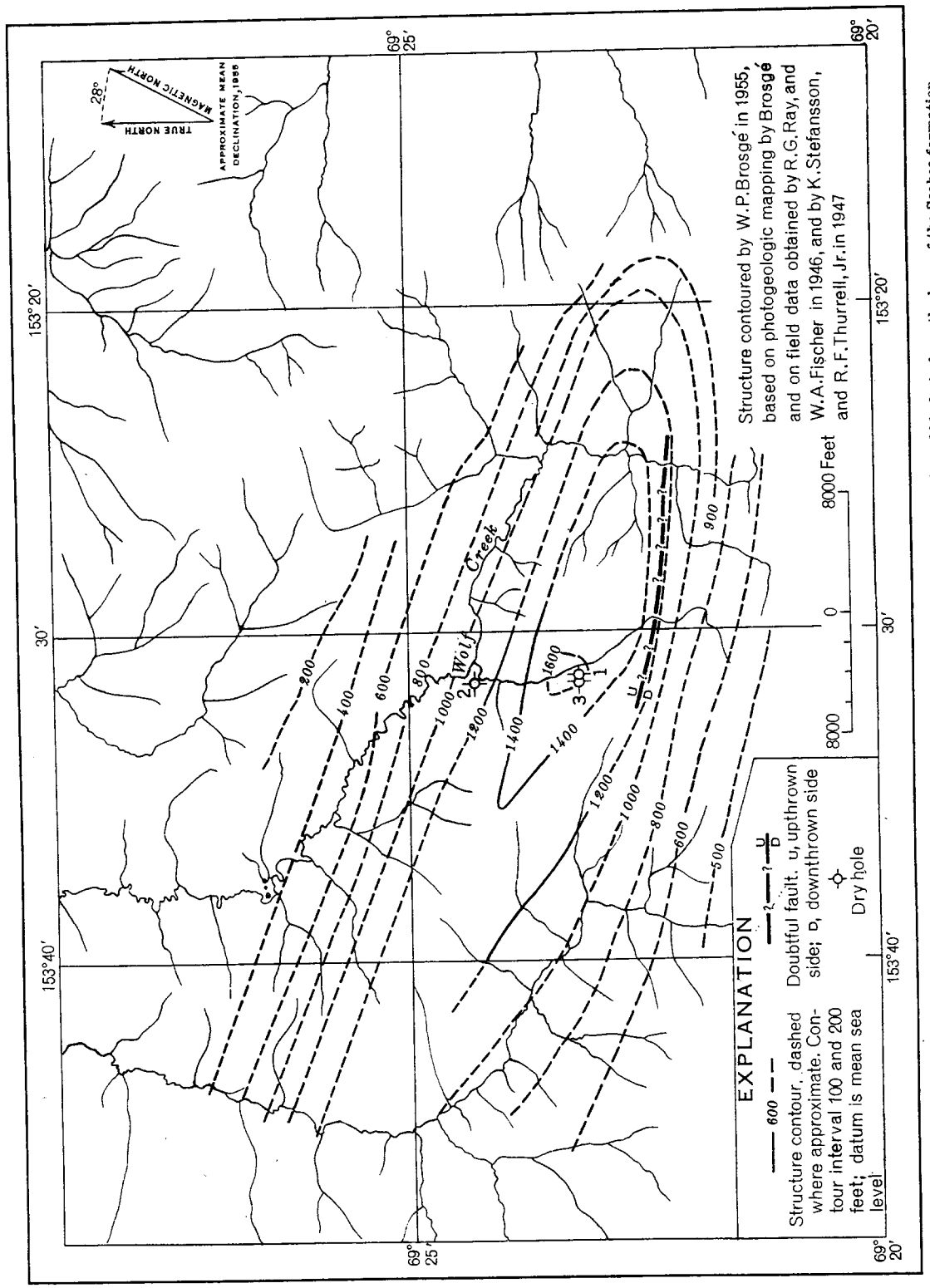


FIGURE 36.—Structure-contour map of the Wolf Creek anticline. The contours are on a horizon 800 feet above the base of the Seabee formation.

sandstone separated into beds 20 to 50 feet thick by beds of clay shale. The sandstone is commonly light medium gray, fine to medium grained, friable, and slightly silty and argillaceous, with a salt and pepper appearance; none of the beds contained oil or gas. The rock is composed of angular to subangular clear and white quartz grains with some gray chert and dark rock fragments. Clay shale, which makes up a little less than half of the formation, is medium to medium dark gray, and is rarely very silty. Siltstone, present in thin beds, is medium gray, argillaceous, and slightly micaceous in part. A minor amount of shaly coal, clay ironstone, and white bentonite are also present, although the last is rare and is limited to the upper part of the formation. A distinctive microfaunal assemblage, the *Gaudryina-Trochammina* fauna, is present in this formation. (See p. 480–481.)

The drill in Wolf Creek test well 2 penetrated similar rocks, but the lithologic units described above vary considerably in thickness, or disappear entirely before reaching this northern test. Some of the sandstone beds can be correlated in the three wells. The uppermost 50 feet of the Ninuluk formation, not present in the other wells, was found to be similar to the rest of the formation, except for a slightly greater amount of bentonite.

The base of the formation is found at the bottom of the thick sandstone beds and below the lowest occurrence of the *Gaudryina-Trochammina* microfauna. The formation is approximately 420 feet thick.

KILLIK TONGUE OF THE CHANDLER FORMATION

The Killik tongue (Lower Cretaceous) of the nonmarine Chandler formation (Nanushuk group), is about 900 feet thick and is composed primarily of clay shale, with some thin beds of sandstone, siltstone, and coal. The clay shale is medium dark gray, and is silty and micaceous in part. A little black clay shale is associated with the coal. The thin sandstone beds differ from those of the Ninuluk formation in being very fine grained, very argillaceous and silty, and slightly to very micaceous; some of the lower beds, which are 10 to 20 feet thick, produced a small amount of gas in Wolf Creek test well 1 and water in Wolf Creek test well 2.

The base of the formation cannot be determined exactly, but the approximate division between the Killik tongue and the underlying Grandstand formation is placed below the lowest bentonite and above a common occurrence of specimens of *Verneuilinoides borealis* Tappan, although a few Foraminifera occur, probably in thin interfingering beds of marine sediments, just above the base of the Killik tongue. (See p. 481)

GRANDSTAND FORMATION

Only the uppermost part of the Grandstand formation was penetrated by Wolf Creek test wells 1 and 2 (150 and 60 feet, respectively). The description below is based on the 1,360 feet drilled in Wolf Creek test well 3. The formation (Lower Cretaceous) is the lowest part of the Nanushuk group in this area. The rocks are marine and consist of about 1,350 feet of alternating sandstone and clay shale with rare siltstone beds. The upper 125 feet consist of medium-dark-gray noncalcareous silty clay shale. This is underlain by 60 feet of medium-light-gray fine-grained slightly silty very slightly micaceous sandstone that is composed of subangular clear and white quartz with rare chert and rock fragments. A few thin beds of clay shale break the continuity of the sandstone. A show of gas and a faint cut of oil in CCl_4 were obtained from this bed. Lower sandstones are very fine to fine grained, range from 15 to 100 feet in thickness, and alternate with 10- to 100-foot beds of clay shale or claystone; sandstone makes up approximately half of the sequence. Two of the sandstones gave slight indications of oil or shows of gas. Porosity of the sandstone beds range from 0.3 to 16 percent and permeability from impermeable to 32 millidarcys, except for a bed at 1,553 feet which had 19 percent porosity and 305 millidarcys permeability. The base of the formation is arbitrarily placed at the bottom of the lowest thick bed of sandstone.

TOPAGORUK FORMATION

The Topagoruk formation (Lower Cretaceous), penetrated on the anticline only by Wolf Creek test well 3, is a sequence of marine rocks differing from the overlying Grandstand formation only by the lack of thick, massive sandstone beds and the greater proportion of fine clastics; the microfauna and characteristic rock types encountered are the same. The formation is composed mostly of medium-dark-gray clay shale, with some beds of medium-light-gray very fine-grained argillaceous silty sandstone and medium-gray argillaceous siltstone. No shows of oil or gas were noted in the 1,000 feet of the Topagoruk formation penetrated by the well. As the base of the formation was not reached, its total thickness in the area is unknown.

WOLF CREEK TEST WELL 1

Location: Lat 69°23′11″ N., long 153°31′15″ W.
Elevation: Ground, 712 feet; derrick floor, 714 feet.
Spudded: April 29, 1951.
Completed: June 4, 1951; junked and abandoned.
Total depth: 1,500 feet.

The first of 3 wells drilled on the Wolf Creek anticline was planned to penetrate the Grandstand for-

mation, which contains the oil-producing sandstone beds of the Umiat oil field about 35 miles to the east, to determine its petroleum content and reservoir possibilities in the Wolf Creek area. The well is about 1,500 feet south of the axis of the anticline. (See fig. 36.) It drilled through a few feet of soil before penetrating rocks of the Nanushuk group. The Ninuluk formation is present from 10 to 455 feet and is underlain by nearly 900 feet of the Killik tongue of the Chandler formation (455 to 1,350 feet). The Grandstand formation was penetrated in the bottom 150 feet of the hole. No shows of oil were noted, but minor amounts of gas flowed from sandstone beds in the Killik tongue; the bottom 10 feet in the well produced 1,304,900 cubic feet of gas per day from the only massive sandstone bed of the Grandstand formation that was reached by the test well. The well was abandoned at 1,500 feet when a core-barrel assembly was lost and could not be recovered from the hole.

The electric log from this well (see pl. 30) reflects the lithology rather poorly; intervals of high resistivity and spontaneous potential on the log rarely correspond with the sandstone beds as indicated by bit cuttings brought up in the bailer and in the cores that were recovered.

DESCRIPTION OF CORES AND CUTTINGS

Descriptions of the rocks penetrated in Wolf Creek test well 1 are based on an examination of cores and cutting samples. Composition as shown on the graphic log is determined in part by interpretation of electric log and may differ slightly from the written description. The material was described dry, and colors were determined by comparison with the Rock Color Chart (Goddard and others, 1948). The depths were measured from the top of the derrick floor.

Abundance of microfossil specimens mentioned at the beginning of each core description is defined as follows: 1–4, very rare; 5–11, rare; 12–25, common; 26–50, abundant; more than 50, very abundant.

Lithologic description

[Where no core is listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
----	0–4	Derrick floor to ground level. The interval between ground level and 50 ft is described from Arctic Contractors driller's log; no samples were taken.
----	4–10	Surface soil.
----	10–20	Sandstone. Top of Ninuluk formation at 10 ft.
----	20–32	Gray shale.
----	32–40	Clay.
----	40–50	Shale, blue, sticky.
----	50–65	Clay shale, medium-light-gray, slightly micaceous, calcareous; with abundant grayish-yellow hard clay ironstone.
----	65–90	Clay shale and clay ironstone, as above; and medium-light-gray very calcareous siltstone with carbonaceous flakes; and medium-light-gray very fine-grained calcareous sandstone consisting of subangular white and clear quartz with some dark rock grains and some carbonaceous streaks.
----	90–92	Coal, black, subvitreous; with blocky fracture.
----	92–115	Clay shale, siltstone, and clay ironstone, as above.
----	115–125	Coal, with a minor amount of sandstone, as above.
----	125–155	Clay shale, as above; coal in upper 10 ft.
----	155–165	Sandstone, medium-light-gray, fine-grained, friable; some clay shale and siltstone.
----	165–180	Sandstone, as above.
----	180–200	Clay shale, as above; with clay ironstone.
----	200–240	Sandstone, light-gray, fine- to medium-grained, friable; composed of angular to subrounded clear and white quartz, some subhedral; gray chert and black rock fragments are numerous, pyrite rare, glauconite and mica absent. The lower 10 ft is calcareous.
----	240–270	Siltstone, medium-light-gray, slightly sandy in part; rare clay shale.
----	270–280	Sandstone, light-gray, argillaceous; some gray shale.
----	280–295	Clay shale, medium-light-gray, very slightly micaceous; siltstone as above in upper 10 ft.
----	295–301	Clay shale and siltstone, as above; and black carbonaceous shale with coal laminae.
----	301–307	Clay shale, medium-gray, hard; very fine laminae of medium-light-gray clay.
----	307–330	Sandstone, medium-light-gray, very fine-grained, very silty, noncalcareous; becomes fine grained and less silty at the base.
----	330–360	Siltstone, interbedded with medium-gray clay shale; laminae of medium-light-gray clay.
----	360–380	Clay shale, with streaks of coal and clay ironstone in upper part.
----	380–405	Sandstone, medium-light-gray, very fine- to fine-grained, noncalcareous, slightly silty and argillaceous.
----	405–410	Siltstone, interbedded with sandstone, and clay shale.
----	410–415	No sample.
----	415–420	Sandstone, with some siltstone, and shale.

Lithologic description—Continued

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	420–437	Clay shale, medium- to medium-dark-gray, silty, slightly micaceous; and medium-light-gray slightly micaceous argillaceous siltstone.
----	437–455	Sandstone, as above.
----	455–460	Sandstone and clay shale. Top of Killik tongue of Chandler formation at 455 ft.
----	460–495	Clay shale, medium- to medium-dark-gray, nonmicaceous, noncalcareous; a small amount of clay ironstone and coal in bottom 15 ft.
----	495–530	Clay shale, as above; and medium-light-gray siltstone; some clay ironstone at 515 ft.
----	530–540	Siltstone, as above; some clay shale, and a minor amount of coal.
----	540–545	Siltstone, clay shale, and coal.
----	545–550	Clay shale and siltstone; some sandstone, clay ironstone, black clay shale, and a minor amount of coal.
----	550–555	Clay shale, with some siltstone.
----	555–560	Coal, with a minor amount of siltstone.
----	560–565	Clay shale, siltstone, and coal.
----	565–568	Sandstone with some coal.
----	568–575	Clay shale and siltstone, calcareous.
----	575–580	Limestone, bluish-gray, slightly argillaceous, very finely crystalline.
----	580–585	Clay shale, medium-gray; a small amount of limestone as above.
----	585–590	Siltstone, with small amounts of gray and black clay shale, coal, and sandstone.
----	590–595	Clay shale, and siltstone with a small amount of clay ironstone.
----	595–615	Clay shale, medium- to medium-dark-gray; some siltstone at the top and the base of the section.
----	615–620	Siltstone and clay shale.
----	620–625	Siltstone, with some clay shale.
----	625–629	Sandstone, with some siltstone.
1	629–634	Recovered 10 in.: Microfossils absent. Clay shale chips, medium-gray; some flakes of carbonized plants; two fragments of medium-light-gray sandy siltstone.
----	634–650	Clay shale and siltstone, with a small amount of clay ironstone.
----	650–655	Sandstone, with a small amount of siltstone.
----	655–662	Clay shale, gray, and coal; with a small amount of sandstone and black clay shale.
----	662–685	Clay shale, with a small amount of coal.
----	685–690	Coal and clay shale.
----	690–695	Clay shale, with some siltstone.
----	695–725	Clay shale, with a minor amount of siltstone in the lower part.
----	725–745	Sandstone, carbonaceous; a small amount of siltstone and clay shale in the upper 10 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	745–750	Siltstone.
----	750–765	Siltstone and clay shale.
----	765–775	Siltstone, with a minor amount of sandstone.
----	775–780	Sandstone, with a minor amount of siltstone, clay shale, and clay ironstone.
----	780–785	Clay shale, with some siltstone and sandstone.
----	785–789	Siltstone, light-gray, noncalcareous; with some medium-gray clay shale.
2	789–794	Recovered 5 ft: Microfossils absent. 2 ft 2 in., clay shale, medium-dark-gray; numerous fine laminae of medium-gray slightly micaceous noncalcareous siltstone, lenticular or cross-bedded in part. Grades into unit below. 2 ft 10 in., claystone, medium-dark-gray, very silty, very micaceous, noncalcareous; some fragments of carbonized plants.
----	794–798	Clay shale.
----	798–815	Clay shale, very silty; some black carbonaceous clay shale and a small amount of sandstone; clay ironstone in lower half of section.
----	815–840	Clay shale and sandstone, medium-light-gray, very fine- to fine-grained, very argillaceous, slightly calcareous in part, slightly glauconitic; carbonaceous patches. Clay ironstone and siltstone also present in lower 10 ft and a few pieces of reddish-brown sandy limestone at 820–825 ft.
----	840–850	Clay shale, with some clay ironstone in upper 5 ft.
----	850–857	Clay shale and coal; a minor amount of black clay shale.
----	857–865	Sandstone, as above; some clay shale and siltstone.
3	865–870	Recovered 3 ft: Microfossils absent. Sandstone, light-gray, fine- to medium-grained, argillaceous, noncalcareous. It is composed of subrounded grains of white and clear quartz and numerous dark grains. Streaks and fragments of carbonized plant remains are scattered throughout. It grades into sandy shale and sandstone at base. Permeameter indicated a sample from 867 ft to be impermeable to air. Effective porosity of the same sample by the Barnes method 5.31 percent.
----	870–885	Clay shale, with some coal, especially in the bottom 5 ft.
----	885–890	Shale, gray and black; with siltstone and coal.
----	890–900	Clay shale, with clay ironstone in the top 5 ft and coal in the bottom 5 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	900–925	Clay shale, medium- to medium-dark-gray, noncalcareous; a minor amount of coal in the upper 10 ft, some clay ironstone in the bottom 15 ft.
----	925–930	Siltstone, with some clay shale, and a minor amount coal.
----	930–935	Clay shale.
4	935–940	No recovery.
----	940–945	Clay shale, with some siltstone.
----	945–950	Clay shale, sandstone, and siltstone.
----	950–995	Clay shale, with a minor amount of clay ironstone, and some siltstone at the base.
----	995–1, 010	Clay shale, with sandstone in the upper 5 ft, and clay ironstone in the lower 10 ft.
----	1, 010–1, 020	Sandstone and clay shale, a minor amount of clay ironstone.
----	1, 020–1, 025	Clay shale and siltstone.
----	1, 025–1, 073	Clay shale, with siltstone streaks.
5	1, 073–1, 077	No recovery.
6	1, 077–1, 080	No recovery.
7	1, 080–1, 084	Recovered 3 ft 3 in.: Microfossils rare. Claystone, medium- to medium-dark-gray, nonmicaceous, noncalcareous; some medium-light-gray slightly silty laminae, commonly crossbedded. A clay ironstone lens one-half inch thick is present 1 ft above the bottom of the core.
----	1, 084–1, 090	Clay shale, black and gray; some sandstone.
----	1, 090–1, 120	Clay shale, with small amounts of clay ironstone, siltstone, and sandstone in the upper 10 ft.
----	1, 120–1, 140	Clay shale and sandstone.
----	1, 140–1, 150	Clay shale.
----	1, 150–1, 160	Sandstone, light-gray, very fine- to fine-grained, argillaceous, micaceous, noncalcareous.
----	1, 160–1, 170	Sandstone, light-gray, medium- to fine-grained, slightly argillaceous; but with many dark rock grains.
8	1, 170–1, 174	Recovered 6 in.: Microfossils absent. Sandstone, light-gray, fine- to medium-grained, argillaceous, noncalcareous; patches and fragments of carbonized plants. The sand grains are subangular white and clear quartz, commonly frosted, with gray chert and some dark rock fragments. Mica, pyrite, and glauconite are very rare or absent.
9	1, 174–1, 175	No recovery.
10	1, 175–1, 178	No recovery.
----	1, 178–1, 225	Clay shale, light- to medium-gray; a minor amount of siltstone.
----	1, 225–1, 235	Sandstone, very fine- to fine-grained, argillaceous; with clay shale.
----	1, 235–1, 250	Siltstone, medium-gray, very sandy, slightly argillaceous, micaceous, noncalcareous; a small amount of clay shale.
----	1, 250–1, 270	Sandstone, fine-grained; with gray clay shale and siltstone in upper 10 ft.
----	1, 270–1, 273	No sample.
11	1, 273–1, 278	Recovered 2 ft 6 in.: Microfossils absent. Siltstone, medium-gray, argillaceous, slightly sandy, very slightly micaceous, noncalcareous. The silt grains are similar in composition to the sand grains of core 8, but are more angular and have a larger percentage of dark rock fragments. Grades into silty claystone at base.
----	1, 278–1, 290	Sandstone, with some clay shale and clay ironstone in upper 7 ft.
12	1, 290–1, 293	Recovered 2 ft 6 in.: Microfossils absent. Sandstone, as in core 8. At 1,292 ft the rock has a porosity of 7.02 percent and is impermeable.
----	1, 293–1, 300	Bentonite, white to yellowish-white; abundant rounded grains of a yellowish translucent material and rare euhedral biotite plates.
----	1, 300–1, 310	Clay shale.
----	1, 310–1, 350	Clay shale, with a small amount of bentonite and sandstone; medium-gray very sandy slightly argillaceous noncalcareous micaceous siltstone in upper 10 ft.
----	1, 350–1, 400	Clay shale, medium-gray; a minor amount of clay ironstone. Top of Grandstand formation at 1350 ft.
----	1, 400–1, 420	Siltstone, medium-gray, very argillaceous.
----	1, 420–1, 485	Clay shale, medium-dark-gray, very silty; carbonaceous streaks and streaks of siltstone; a small amount of bentonite at 1,435–1,445 ft.
----	1, 485–1, 492	Siltstone, with sandstone, and some bentonite.
----	1, 492–1, 500	No sample. Arctic Contractors' well geologist, Marvin Heany, described the interval as sandstone.

466290—59——5

LOGISTICS

A drilling foreman and a geologist supervised the drilling of Wolf Creek test well 1. The drilling crew included 2 drillers, 2 tool dressers, 1 fireman, 1 heavy-duty-equipment mechanic and welder; 5 other men—1 cook, 1 kitchen helper, 1 janitor, 1 Caterpillar-tractor operator, and 1 warehouseman-timekeeper—were also permanently employed at the site. Electricians, additional tractor operators, and the electric-log operator came from Barrow or Umiat as they were needed.

Housing consisted of 15 wanigans; 2 were used for dormitories, 2 for water storage, and the others for 1 galley, 1 messhall, 1 radio room and store, 1 food warehouse, 1 generator and boiler room, 1 geological and

engineering office, 1 machine shop, and 1 utility room; and some were used for electric-log-equipment storage, cement storage, and cement-pump housing. The wanigans and other equipment used by Arctic Contractors were brought to the site from Barrow by a tractor train, and men were flown in by a small plane. Vehicles used locally were 2 D8 Caterpillar tractors, 3 weasels, and a TD–9 small crane (cherrypicker). The well was drilled with a Bucyrus-Erie spudder, a model-29 water-well drill with a 45-foot all-steel mast. Power was furnished by a Caterpiller D–3400 6–cylinder diesel engine; a Kohler 4.0-kilowatt light plant and a Heat-Pak boiler were also used.

During the last 3 weeks of drilling (from 865 to 1,500 feet), 3,871 gallons of diesel fuel and 404 gallons of 72-octane gasoline were burned, 101 gallons of lubricating oil and 16 pounds of grease were consumed, and 57,000 gallons of water was used. No records of consumption are available for the first part of the drilling.

DRILLING AND TESTING OPERATIONS AND GAS ANALYSES

The Bucyrus-Erie spudder was mounted on a welded-steel sled and was set on 12 by 12-inch timbers at the well site. A summary of drilling and testing records compiled largely from data recorded by Arctic Contractors' engineer, Marvin Heany, is given below. Gas analyses made by the U. S. Bureau of Mines' Petroleum Experiment Station at Bartlesville, Okla., are also included.

Notes from drilling records

Depth (feet)	*Remarks*
49	An 11¾-in. 45-lb casing was set at 48 ft with 21 sacks of Cal-Seal poured around the casing, cementing it solidly to the wall of the hole.
210	Fresh water was used as a drilling fluid to 210 ft; below that depth, brine made of 35 lb of salt per bbl of water was used.
378	An 8-ft section of the bailer dump stem was lost in the hole and then drilled up.
863	A slight flow of gas was noted at 863 ft; the closed-in pressure at the surface was 40 lb after 5 min, in spite of a leaking 10-in. ram.
865	Operations were shut down for 3 days, waiting for a new ram. The gas flow was then tested with a critical flow prover and results are given below.

Orifice (in.)	Pressure (psi)	Temperature (°F)	Volume (cu ft per day)
⅜	20.2	14	116,000
¼	32.5	25	71,100
⅛	42.75	22.5	21,250

The gas recovered during this test contained 4.4 percent noncondensables, 95.1 percent methane, 0.2 percent ethane, and 0.3 percent propane, by volume, according to an analysis by the U. S. Bureau of Mines. After the test the well was killed with 200 ft of salt water, and drilling was resumed.

875	Gas started to flow while the tools were being withdrawn from the hole, and an explosion set fire to the canvas rig housing, destroying it and electrical connections and belts. The rig was not seriously damaged, and drilling started again after 2 days for repairs, during which the 10-in. gate was replaced with a 11¾-in. high-pressure gate. The hole was filled to 200 ft with brine.
960	Fluid was bailed from the hole, the rams closed and the well shut in. Pressure rose to 60 psi in an hour, and to 70 psi at the end of the second hour. The rams were opened and the gas bled off. The hole was found dry, and drilling was continued.
1,175	Show of gas in sandstone at 1,152 to 1,175 ft.
1,496	The flow of gas increased while the hole was being drilled at 1,491 ft. After coring from 1,492 to 1,496 ft, the gate valve was shut and pressure built up to 60 lb in 30 min.
1,500	While a core was being taken at 1,500 ft, the core barrel assembly was lost in the hole and could not be recovered. After waiting a day for a 2-in. critical flow prover and electric logging equipment, a test of the gas flow gave the following results:

Orifice (in.)	Pressure (psi)	Temperature (° F)	Volume (cu ft per day)
¾	53	33	881,300
⅜	100	35	397,100

The gas was analyzed by the U. S. Bureau of Mines and found to contain 0.15 percent nitrogen, 99.55 percent methane, 0.15 percent ethane, and 0.15 percent propane. After the test the hole was filled with fresh water. The flow of gas stopped and the rock absorbed some of the water. An electric log from 437 to 1,407 ft was made with hand-recording Schlumberger equipment, and the water level was located at 330 ft. The fresh water in the hole apparently affected the spontaneous potential, so the curve does not clearly reflect lithologic changes. Bridges at 820–850 and 1,325–1,475 ft were cleaned out, and the hole again filled with fresh water. After making an electric log from 1,400 to 1,450 ft, the hole was shut in and abandoned. The top of the casing, at ground level, was surmounted by a collar, a nipple, a flange, and a flanged gate. A 2-in. collar is welded into the nipple and a small nipple and 125 psi brass gate valve project from the collar.

The 25 bits used to drill the well were redressed at the well site by hard-surface welding. A Baker cable-tool core bit 6 was used for coring, and 3 core heads took 51 ft of core, of which 17 ft were recovered.

WOLF CREEK TEST WELL 2

Location: Lat 69°24'17" N., long 153°31'15" W.
Elevation above sea level: Ground, 437 feet; derrick floor, 443 feet.
Spudded: June 6, 1951.
Completed: July 1, 1951; dry and abandoned.
Total depth: 1,618 feet.

Wolf Creek test well 2 is about 1¼ miles north of Wolf Creek test well 1, on the north flank of the Wolf Creek anticline. The purpose of the well was to determine whether the gas-bearing sandstone beds penetrated in Wolf Creek test well 1 contained oil in a lower structural location. A weak blow of gas at 768 feet and a slight show of gas in the shale of core 2 (768–770 feet) were the only evidence of hydrocarbons in the well. A sandstone bed from 940 to 960 feet produced 20 gallons of water per hour. The water had a sodium-chloride content of 9,405 parts per million. A few sandstone beds in the upper part of the hole appeared permeable, but most are very argillaceous and silty. Sandstone cores were too badly broken to be suitable for testing.

Wolf Creek test well 2 is 213 feet lower structually than Wolf Creek test well 1 and is the only Wolf Creek test to penetrate beds of the Seabee formation (Colville group, Upper Cretaceous, 45 to 130 feet) beneath the mantle of alluvial gravel and clay (6 to 45 feet). The drill passed through the Ninuluk formation (130 to 650 feet) and the Killik tongue of the Chandler formation (650 to 1,545 feet) into the upper part of the Grandstand formation (1,545–1,618 feet). The greatest depth to which the rig could drill was 1,618 feet, and the well was abandoned without reaching the base of the Grandstand formation.

DESCRIPTION OF CORES AND CUTTINGS

Descriptions of the rocks penetrated in Wolf Creek test well 2 are based on examination of cores and cutting samples. Composition as shown on the graphic log, however, is determined in part by interpretation of the electric log. The material was described dry, and colors were determined by comparison with the Rock Color Chart (Goddard and others, 1948). The depths were measured from the top of the derrick floor.

Abundance of microfossil specimens given in each core description is defined as follows: 1–4, very rare; 4–11, rare; 12–25, common; 26–50, abundant; more than 50, very abundant.

Lithologic description

[Where no core is listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
----	0–6	Derrick floor to ground level.
----	6–15	"Tundra, clay, silt, and ice." From a report by Arctic Contractors' well geologist.
----	15–25	Sand and gravel; grains medium sand size to three-eighths inch in diameter, composed of yellow and black chert; well rounded or rarely subangular, with rare white chert and milky quartz. Some broken pebbles and concentrically ringed concretions of clay ironstone, dark red (hematitic) and grayish-yellow (limonitic). A small amount of very fine to coarse sand, consisting of subangular grains of white and clear quartz with some chert and ironstone.
----	25–45	Clay, light-olive-gray, very slightly and very finely micaceous, noncalcareous; some gravel (cavings from above?).
----	45–75	Clay shale, medium- to medium-light-gray, slightly micaceous, noncalcareous; some light-gray silty bentonitic laminae near base; rare clay ironstone. Top of Seabee formation at 45 ft.
----	75–80	Bentonite, very light-yellowish-gray, unctuous; plastic when wet; euhedral biotite and flat, angular quartz grains are common.
----	80–90	Clay shale, as above; olive- and medium-gray very argillaceous slightly micaceous noncalcareous siltstone. Some light-olive-gray very fine-grained very silty slightly argillaceous calcareous hard sandstone; olive tinge caused by limonitic cement.
----	90–120	Siltstone, olive- and medium-gray. Sandy in lower part, with some shale and a minor amount of clay ironstone.
----	120–130	Siltstone, medium-gray; some very fine- to fine-grained friable sandstone composed of subangular white and clear quartz grains.
----	130–140	Clay shale, medium-dark-gray; some siltstone that has clay laminae. Top of Ninuluk formation at 130 ft.
----	140–150	Clay ironstone, some medium-light-gray and black clay shale, siltstone, and coal.
----	150–160	Siltstone, medium-light-gray; with thin beds of light-olive-gray siltstone.
----	160–170	Clay shale, medium-gray; a minor amount of dark-red clay ironstone, coal, and black shale.
----	170–180	Bentonite, light-gray, as in interval from 75–80 ft; a small amount of clay shale.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	180–190	Coal, and gray and black clay shale.
----	190–200	Sandstone, medium-light-gray, very calcareous; like sandstone at 80–90 ft but lacking limonitic cement; some siltstone.
----	200–220	Clay shale, medium-light-gray, calcareous in part; some medium-light-gray partly calcareous siltstone.
----	220–240	Clay shale, dark- to medium-dark-gray.
----	240–260	Siltstone, medium-light-gray, very to slightly argillaceous, slightly calcareous; clay shale in upper half.
----	260–280	Sandstone, very fine-grained, very silty, nonmicaceous, calcareous; beds of siltstone in upper 10 ft.
----	280–290	Clay shale, medium-dark-gray; with siltstone, sandstone, grayish-yellow clay ironstone, black shale, and coal.
----	290–310	Siltstone, with some clay shale and sandstone.
----	310–320	Coal, black, shiny; blocky to subconchoidal fracture; shaly cleavage; a small amount of bentonite and clay shale.
----	320–360	Sandstone, light-gray, very fine-grained, becoming fine-grained with depth, slightly argillaceous, noncalcareous; composed of subrounded white and clear quartz, with gray chert and dark rock fragments; carbonaceous flakes present; a few yellow grains; no limonitic cement.
----	360–380	Siltstone, medium-gray, very argillaceous, slightly calcareous in part; medium-gray clay shale in lower 10 ft.
----	380–410	Clay shale, medium-gray, nonmicaceous, noncalcareous; some sandstone and siltstone in lower 10 ft.
----	410–425	Sandstone, very fine- to fine-grained, friable; composed of white and clear quartz grains, rarely frosted, with some gray and black chert and dark rock fragments.
----	425–430	No sample.
----	430–440	Clay shale with siltstone.
----	440–450	Siltstone, sandy, very fine-grained, very silty and argillaceous; grades to sandstone; a small amount of shale.
----	450–500	Clay shale, medium- to medium-dark-gray, very uniform, nonmicaceous; a small amount of siltstone in the top 10 ft.
----	500–525	Sandstone, very fine- to fine-grained, friable, as in sandstone at 410 ft.
----	525–535	Clay shale, medium-gray, silty in part.
----	535–545	Limestone, medium-gray, argillaceous, dense; with siltstone, clay shale, and minor amounts of coal and ironstone.
----	545–565	Clay shale.
----	565–585	Sandstone, mostly very fine-grained, some fine-grained, silty, carbonaceous; coal increases with depth.
----	585–615	Clay shale, with siltstone and sandstone, light-olive-gray, very fine-grained, silty.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	615–625	Siltstone, sandy; grades to very fine-grained, silty sandstone.
----	625–635	Sandstone, light-gray, fine-grained, nonargillaceous, noncalcareous; a small amount of clay shale.
----	635–645	Siltstone, medium-gray; with sand and clay shale.
----	645–655	Clay shale, medium- to medium-dark-gray, nonmicaceous, noncalcareous; streaks of siltstone. Top of Killik tongue of Chandler formation at 650 ft.
----	655–675	Siltstone, some clay shale, especially in upper 10 ft; rare coal and black shale in upper 10 ft; a few pieces of bentonite (?).
----	675–685	Coal and black shale, some siltstone, and a small amount of clay shale.
----	685–695	Siltstone, some clay shale and rare light-olive-gray very fine-grained very silty sandstone.
----	695–705	Siltstone and clay shale, with a little coal and black shale.
----	705–715	Clay shale.
----	715–725	Clay shale, with siltstone, sandstone, and some clay ironstone.
----	725–742	Siltstone and sandstone, olive-gray, very silty; carbonaceous laminae.
1	742–745	Recovered 6 in.: Microfossils absent. Clay shale, medium-gray, silty, slightly micaceous, calcareous; poor shaly cleavage.
----	745–750	Clay shale, calcareous in part; some siltstone and clay ironstone.
----	750–755	Coal and sandstone, fine- to medium-grained, calcareous; with gray and black clay shale.
----	755–760	Siltstone.
----	760–765	Clay shale and siltstone, some sandstone, and a small amount of clay ironstone.
----	765–768	Clay shale, with streaks of siltstone.
2	768–770	Recovered 5 in.: Microfossils absent. Claystone, (one fragment), medium-gray, very silty, slightly micaceous, noncalcareous; rare carbonaceous flakes, and one grain of amber.
----	770–775	Coal, black and gray clay shale, and siltstone.
----	775–790	Clay shale, with some sandstone at 780–785 ft.
----	790–795	Clay shale, siltstone, and a little sandstone
----	795–800	Siltstone, with some clay shale.
----	800–810	Clay shale, with some siltstone in the upper part.
----	810–815	Clay shale, with siltstone and very fine-grained very silty sandstone.
----	815–825	Clay shale, with some siltstone and coal in the lower 5 ft.
----	825–830	Siltstone and clay shale.
----	830–835	Clay shale, dark-gray, silty, carbonaceous; grades into siltstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	835–840	Clay shale, medium-gray; a little coal and black shale.
----	840–850	Clay shale, bentonitic; with black shale in the upper half.
----	850–860	Coal, with black shale, and siltstone. Siltstone is brownish red with black sand-size coal particles.
----	860–865	Claystone, light-gray, waxy; slickensides; medium-light-gray very fine-grained very silty and argillaceous noncalcareous sandstone.
----	865–880	Clay shale, medium-light- to medium-dark-gray.
----	880–885	Siltstone, medium-light-gray, and clay shale.
----	885–890	Claystone, medium-light-gray, slightly waxy, noncalcareous, nonbentonitic.
----	890–895	Siltstone, medium-gray; a few reddish-brown siltstone fragments.
----	895–900	Sandstone, very fine-grained, very silty and argillaceous, noncalcareous; some siltstone and streaks of clay shale.
----	900–920	Clay shale, medium- to medium-dark-gray, silty in part.
----	920–925	Coal.
----	925–935	Sandstone, medium-gray, very fine-grained, silty, argillaceous, noncalcareous; a small amount of siltstone and coal.
----	935–940	Siltstone.
----	940–943	Sandstone, light-gray, very fine-grained, silty, noncalcareous; siltstone and some clay shale.
3	943–946	Recovered 2 ft: Microfossils absent. 1 ft 6 in., sandstone, medium-light-gray, fine-grained, very silty and argillaceous, micaceous, noncalcareous; grains are composed of clear and white quartz, white and gray chert, dark rock fragments, and rare carbonaceous material. 6 in., clay shale fragments, medium-dark-gray, slightly silty, slightly micaceous, noncalcareous; rare carbonaceous particles.
----	946–955	Sandstone, as in core 3.
----	955–960	Clay shale, with clay ironstone and streaks of sandstone.
4	960–963	No recovery.
5	963–968	Recovered 5 ft: Microfossils absent. Sandstone, medium-light-gray, medium-grained, salt and pepper, argillaceous, slightly micaceous, noncalcareous; the subangular to subrounded grains are composed of white and clear quartz, white and gray chert, and dark rock fragments. Flakes and fragments of carbonaceous material are common throughout. Two layers, 2 to 3 in. thick, of intraformational conglomerate are present 1 ft below the top and 6 in. above the base of the core; they consist of subangular to rounded chips (as much as 1 in. in diameter) of medium-gray clay shale, light-yellowish-gray clay ironstone, and coal, in a sandstone matrix.
----	968–970	No sample.
----	970–990	Clay shale, medium-dark-gray, very silty; some siltstone in upper part.
----	990–995	Sandstone, with siltstone and clay shale.
----	995–1,000	Clay shale, medium- to medium-dark-gray.
----	1,000–1,005	Sandstone, with some siltstone.
6	1,005–1,010	Recovered 5 ft: Microfossils absent. Clay shale, medium- to medium-dark-gray, silty, slightly micaceous, noncalcareous; rare flakes of carbonaceous material; laminae of medium-gray siltstone are rare at the top, more numerous, thicker, and sandy at the base of the section.
----	1,010–1,015	Siltstone.
----	1,015–1,030	Clay shale, medium-light- and medium-dark-gray, with medium-gray siltstone in lower 10 ft.
----	1,030–1,035	Coal, with a little black shale.
----	1,035–1,045	Clay shale, medium-gray; and medium-light-gray siltstone.
----	1,045–1,050	Clay shale, with some clay ironstone.
----	1,050–1,075	Clay shale, medium-light- to medium-dark-gray, slightly silty, medium-dark-gray siltstone at 1,065–1,070 ft.
----	1,075–1,085	Siltstone, medium-dark-gray; with clay shale in the lower part.
----	1,085–1,090	Clay shale, with a small amount of siltstone.
----	1,090–1,105	Clay shale, siltstone, and sandstone, medium-light-gray, very fine-grained, silty, argilaceous; with carbonaceous laminae.
----	1,105–1,115	Clay shale, medium-gray.
----	1,115–1,120	Coal.
----	1,120–1,135	Coal and black shale.
----	1,135–1,165	Clay shale, medium-gray; with streaks of coal, black shale, and some clay ironstone in the upper part; some siltstone in the lower 15 ft. A small amount of tan waxy nonbentonitic noncalcareous clay is at 1,160–1,165 ft.
----	1,165–1,170	Clay shale, medium-gray and black, and siltstone.
----	1,170–1,175	Sandstone, with black shale and siltstone.
----	1,175–1,180	Siltstone.
----	1,180–1,195	Clay shale, with some siltstone and sandstone at the base.
----	1,195–1,203	Siltstone, with some sandstone and shale.
7	1,203–1,208	Recovered 5 ft: Microfossils absent. 1 ft 8 in., clay shale, as in the upper part of core 6; an ironstone concretion 6 in. below the top.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		1 ft 4 in., interlaminated coal and clay shale, dark-gray, nonmicaceous, noncalcareous; a few small curved slickensides, probably caused by minor slips during compaction.
		7 in., clay shale, medium-gray, very silty, micaceous, noncalcareous; grades through medium-light-gray siltstone to unit below.
		1 ft 5 in., sandstone, medium-light-gray, very fine- to fine-grained, very argillaceous, slightly micaceous, noncalcareous; composed of white and clear quartz, white and gray chert, with rare dark rock and coal particles.
8	1, 208–1, 211	Recovered 3 ft: Microfossils absent.
		1 ft 7 in., sandstone, as above. Grades into unit below.
		1 ft 5 in., siltstone, interbedded with clay shale; siltstone is medium light gray, noncalcareous, slightly micaceous, and slightly sandy; clay shale is medium gray, noncalcareous, with a few carbonaceous partings.
----	1, 211–1, 215	Siltstone, with some sandstone and shale.
----	1, 215–1, 235	Clay shale, medium-gray.
----	1, 235–1, 255	Clay shale, with some sandstone; grades to sandstone with a little siltstone and shale.
----	1, 255–1, 260	Clay shale, with some siltstone.
----	1, 260–1, 275	Sandstone, with siltstone and clay shale in the upper 5 ft.
----	1, 275–1, 280	Clay shale, medium-gray.
----	1, 280–1, 300	Siltstone, medium-light-gray.
----	1, 300–1, 310	Clay shale, with a very small amount of light-yellowish-gray clay shale.
----	1, 310–1, 320	Siltstone, with clay shale, and some sandstone.
----	1, 320–1, 330	Clay shale.
----	1, 330–1, 335	Siltstone.
----	1, 335–1, 380	Clay shale, with rare siltstone.
----	1, 380–1, 390	Clay shale, medium-gray; with siltstone, and rare coal, and black shale.
----	1, 390–1, 396	Siltstone, with some sandstone and clay shale.
9	1, 396–1, 400	Recovered 4 ft: Microfossils absent.
		1 ft 6 in., clay shale, medium-dark-gray, noncalcareous, nonmicaceous.
		2 ft 6 in., sandstone, as in the upper part of core 8.
----	1, 400–1, 405	Clay shale, with some sandstone and siltstone in the lower half.
----	1, 405–1, 410	Sandstone, with some siltstone and clay shale.
----	1, 410–1, 415	Clay shale.
----	1, 415–1, 440	Clay shale, silty; some siltstone in the upper part.
----	1, 440–1, 450	Clay shale and siltstone, as above, with a little coal.
----	1, 450–1, 455	Clay ironstone and sandstone, with clay shale and siltstone.
----	1, 455–1, 460	Siltstone, with some clay shale and a small amount of sandstone and clay ironstone.
----	1, 460–1, 490	Clay shale, with carbonaceous flakes; some siltstone, and sandstone at 1,465–1,470 and 1,485–1,490 ft.
----	1, 490–1, 505	Siltstone, with some clay shale; coal in lower 5 ft.
----	1, 505–1, 510	Clay shale, with rare siltstone.
----	1, 510–1, 520	Clay shale, gray and black, with coal; siltstone in lower half.
----	1, 520–1, 525	Siltstone, clay shale, and sandstone.
----	1, 525–1, 530	Clay shale, with rare sandstone and siltstone.
----	1, 530–1, 535	No sample.
----	1, 535–1, 545	Clay shale and siltstone; some sandstone in upper 5 ft.
----	1, 545–1, 555	Clay shale, with a small amount of siltstone. Top of Grandstand formation is placed at 1,545 ft.
----	1, 555–1, 560	Siltstone, with clay shale and sandstone.
----	1, 560–1, 575	Clay shale, with some sandstone, black shale, and clay ironstone.
----	1, 575–1, 585	Siltstone, with clay shale, and a small amount of black shale and sandstone.
----	1, 585–1, 593	Coal and gray shale, a small amount of black shale.
----	1, 593–1, 600	Sandstone, medium-light-gray, very fine- to fine-grained, micaceous, noncalcareous; with siltstone and clay shale.
----	1, 600–1, 605	Clay shale, with streaks of siltstone.
----	1, 605–1, 610	Sandstone, medium-light-gray, very fine- to fine-grained, noncalcareous; some siltstone and clay shale.
----	1, 610–1, 615	Siltstone, with some clay shale.
10	1, 615–1, 618	Recovered 1 ft: Core not received in Fairbanks laboratory; rock described by well geologist as "clay shale, dark-gray, slightly sandy, very slightly carbonaceous, hard."

LOGISTICS AND DRILLING OPERATIONS

The crew and equipment used in drilling Wolf Creek test well 2 were the same as those for the first Wolf Creek test. The water supply for the second hole was taken from Wolf Creek with a stationary pump and was not measured; petroleum products consumed included 3,829 gallons of diesel fuel, 207 gallons of gasoline, 17.5 gallons of lubricating oil, and 18 pounds of grease.

The drilling operations summarized below were recorded by Marvin A. Heany, Arctic Contractors' petroleum engineer.

Notes from drilling records

Depth (feet)	Remarks
53	Set 53 ft of 11¾-in. 54-lb seamless 8-thread casing at 53 ft, and cemented it with 7 sacks of Cal-Seal poured between the casing and the wall of the hole.
60	Drilling fluid was changed from fresh water to brine made of 25 to 35 lb of salt per bbl of water.
725	Bits 7, 8, 9, and 10 were battered in drilling through hard rock at 725–726 ft.
768	A slight show of gas was noted while drilling at 768 ft.
900	Below 900 ft, salt was added to the water at irregular intervals and in amounts less than 20 lb per bbl of water, because of the difficulty of keeping an adequate supply of salt at the rig.
961	Water entered the hole from a sandstone bed at 940–960 ft. A 3-hr bailing test showed it to be entering at a rate of 20 gal per hr. Salinity was 9,400 parts per million sodium chloride.
980	Broke sand-line sheave and installed new one in 4 hr. Bailing showed that water was entering the hole at a rate of 20 gal per hr.
1,060	Water was shown by bailing test to be still entering the hole at the same rate as before.
1,155	The dump-bailer chain was lost in the hole, but drilling proceeded past it with no difficulty.
1,185	Water entering the hole decreased to 10 gal per hr.
1,280	The drive shaft operating the drawworks from the power unit was twisted off, and operations were shut down 39 hr for repairs. The hole was then found to be bridged at 1,160 ft and, after cleaning it out to 1,280 ft, 27 bailers of mud and water were recovered. The water contained 9,405 parts per million sodium chloride.
1,400	Changed to a lighter string of stem and jars.
1,600	The Baker core barrel was lowered in the hole, but it did not get to the bottom because of caving shale. The hole was cleaned out to the bottom with bit 25. The hole was crooked and caused the drilling line to wear excessively.
1,618	After coring from 1,615 to 1,618 ft, the hole was filled with fresh water, but a large amount was absorbed by the rock, and the water level could not be brought above 241 ft. The fresh water caused the rock to cave, and the sonde for the electric log could not be lowered past 1,128 ft. As in Wolf Creek test well 1, the fresh water apparently affected the self-potential curve, so that it did not clearly reflect lithologic changes. A 11¾-in. collar was placed on top of the casing at ground level, and the well was abandoned.

WOLF CREEK TEST WELL 3

Location: Lat 69°23′11″ N., long 153°31′25″ W.
Elevation: Ground, 732 feet; kelly bushing, 750 feet.
Spudded: August 20, 1952.
Completed: November 3, 1952; dry and abandoned.
Total depth: 3,760 feet.

Wolf Creek test well 3, the second test on the crest of the anticline, was planned to test the sandstone beds of the Grandstand formation which were oil-bearing in the Umiat field and which were not reached by the first two Wolf Creek wells. The well is 485 feet west of Wolf Creek test well 1 and is in a similar structural position, being only 30 feet lower structurally than the first test.

Below 12 feet of unsampled deposits, possibly alluvium (18 to 30 feet), the hole went through the Ninuluk formation (30 to 500 feet), the Killik tongue of the Chandler formation (500 to 1,400 feet), the Grandstand formation (1,400 to 2,760 feet), and 1,000 feet of the Topagoruk formation before being abandoned at 3,760 feet.

Because Wolf Creek test well 1 was an adequate test of the beds above 1,500 feet, no cores or tests were made in Wolf Creek test well 3 above that depth. A few shows of gas were obtained in 5 formation tests between 1,500 and 2,100 feet. The quantity of gas available appeared sufficient to heat a small camp in the vicinity but was inadequate for commercial use. Below 2,100 feet only 2 of 5 formation tests recovered any petroleum—a very weak blow of gas in 1 case and 2 gallons of oil in the other. The oil may have come from the oil-emulsion mud with which the hole was drilled.

DESCRIPTION OF CORES AND CUTTINGS

Descriptions of the rocks penetrated in Wolf Creek test well 3 are based on examinations of cores and cutting samples. Composition as shown on the graphic log, however, is determined in part by interpretation of the electric log. The material was described dry, and colors were determined by comparison with the Rock Color Chart (Goddard and others, 1948). The depths were measured from the top of the kelly bushing.

Abundance of microfossil specimens mentioned at the beginning of each core description is defined as follows: 1–4, very rare; 5–11, rare; 12–25, common; 26–50, abundant; more than 50, very abundant.

Lithologic description

[Where no core is listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
----	0–18	Kelly bushing to ground level.
----	18–30	No sample.
----	30–40	Sandstone, medium-light-gray, very fine-grained, slightly argillaceous and silty, slightly calcareous; some grayish-yellow argillaceous calcareous siltstone that grades to very fine-grained sandstone. Top of Ninuluk formation at 30 ft.
----	40–60	Claystone, medium-gray, slightly silty, slightly calcareous, nonmicaceous; and sandstone as above, with very small amount siltstone in upper part.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	60–70	Claystone, as above; and medium-dark-gray slightly silty in part nonmicaceous clay shale.
----	70–90	Clay shale, as above; with claystone and a small amount of sandstone and grayish-yellow noncalcareous clay ironstone with conchoidal fracture in the lower half.
----	90–100	Siltstone, medium-light-gray, slightly calcareous, argillaceous.
----	100–110	Siltstone, with claystone and clay shale as described above.
----	110–120	Clay shale; with very fine grained slightly calcareous to calcareous sandstone; and siltstone; and a trace of claystone and clay ironstone.
----	120–130	Siltstone, with a small amount clay shale.
----	130–140	Clay shale, medium-dark-gray; and black clay shale with coaly partings; some siltstone, and a trace of coal.
----	140–150	Siltstone, with a very small amount clay shale, clay ironstone, and sandstone.
----	150–160	Siltstone, and clay shale.
----	160–170	Sandstone, yellowish-gray, fine-grained, salt and pepper, very slightly argillaceous and silty, noncalcareous, friable; some siltstone and a trace of black shale, coal, and white and pinkish-white bentonite.
----	170–180	Siltstone, partly sandy, noncalcareous; trace of sandstone and clay ironstone.
----	180–210	Sandstone, as above, slightly calcareous in part; composed of white and clear quartz, gray chert, brown and dark rock fragments, and rare green grains. Grains are angular to subangular, commonly frosted. Some slightly calcareous claystone in the lower 10 ft.
----	210–230	Sandstone, as above, but fine- to medium-grained; some claystone in the bottom half. Electric log indicates claystone at 210–240 ft.
----	230–240	Sandstone, fine-grained, not silty or argillaceous; very slightly calcareous; a very small amount claystone is slightly calcareous to very calcareous.
----	240–250	Claystone, with some sandstone as above.
----	250–290	Sandstone, light-gray, fine- to medium-grained, salt and pepper, nonsilty, noncalcareous, a large proportion of rock fragments in the sand grains. Medium-gray calcareous claystone is very rare.
----	290–300	Sandstone, as above; with some claystone.
----	300–360	Claystone, medium-gray, slightly calcareous, and some medium-dark-gray noncalcareous clay shale; grades with depth to a greater amount of clay shale and less claystone. A small amount of siltstone is at 320–340 ft, and a small amount of sandstone at 310–320 and 340–360 ft.
----	360–370	Sandstone, light-gray, very fine- to fine-grained, slightly silty, noncalcareous; some clay shale and claystone.
----	370–380	Sandstone, very fine-grained, silty, argillaceous, micaceous.
----	380–390	Clay shale, medium-dark-gray; a very small amount siltstone and claystone.
----	390–400	Siltstone, claystone, and clay shale, with a very small amount sandstone.
----	400–430	Clay shale, medium-dark-gray, noncalcareous.
----	430–460	Sandstone, very fine-grained, salt and pepper, slightly silty, noncalcareous; it is fine grained in upper 10 ft with a trace of clay shale.
----	460–500	Sandstone, very fine-grained, very silty and argillaceous, slightly calcareous in part; a small amount clay shale at 460–480 and 490–500 ft, and a trace of clay ironstone at 480–490 ft.
----	500–530	Clay shale, medium-dark- to dark-gray; a small amount medium-gray siltstone and sandstone and a trace of clay ironstone at 500–510 ft. Top of Killik tongue of Chandler formation at 500 ft.
----	530–540	Clay shale, with some claystone, trace of siltstone and sandstone.
----	540–560	Siltstone, with clay shale, and some slightly calcareous to calcareous sandstone.
----	560–570	Clay shale, with siltstone.
----	570–580	Clay shale, with some siltstone, a very small amount sandstone and claystone, and traces clay ironstone, black shale, and coal.
----	580–590	Sandstone, siltstone, and shale.
----	590–600	Siltstone and sandstone, medium-light-gray, very argillaceous, slightly calcareous in part.
----	600–610	Siltstone, a small amount of sandstone and clay shale.
----	610–620	Sandstone, noncalcareous, with siltstone and clay shale.
----	620–630	Clay shale, silty; and siltstone, with a a trace of sandstone.
----	630–685	Clay shale, medium-dark-gray, silty; a small amount of slightly calcareous siltstone.
----	685–700	Clay shale, medium-dark-gray, slightly silty.
----	700–740	Clay shale, with some black shale and coal.
----	740–790	Clay shale, medium-dark-gray, slightly silty in part, noncalcareous. A trace of sandstone at 760–770 ft composed of clear quartz. A small amount black shale and trace of coal in the lower 20 ft.
----	790–800	Siltstone, medium-light-gray, very argillaceous, noncalcareous; a small amount clay shale and sandstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	800–810	Sandstone and siltstone; a very small amount clay shale.
----	810–830	Clay shale, silty; grades to siltstone; very fine-grained silty argillaceous micaceous siltstone and sandstone, with rare carbonaceous flakes. Sand grains are clear quartz, with some white quartz and rare rock fragments.
----	830–840	Clay shale, with a very small amount black shale.
----	840–850	Clay shale, black; some medium-dark-gray clay shale, and a small amount coal.
----	850–860	Clay shale, with a small amount white siltstone having a sugary texture and composed of subangular clear clean quartz grains.
----	860–870	Clay shale, a very small amount light-gray very fine-grained noncalcareous sandstone with a white silty matrix; composed of clear and white quartz with very rare rock fragments. One piece very light-gray cherty limestone.
----	870–880	Clay shale, silty, micaceous; with sandstone as above.
----	880–890	Sandstone, very fine-grained, as above; some clay shale.
----	890–900	Clay shale, silty.
----	900–920	Siltstone, argillaceous; grades to silty clay shale.
----	920–940	Clay shale, medium-dark-gray; some black shale and a small amount coal which increases slightly in the lower part.
----	940–950	Sandstone, very fine-grained, very argillaceous and silty; grades to very sandy siltstone; also clay shale.
----	950–960	Clay shale, with black shale and coal, and a minor amount sandstone.
----	960–970	Clay shale, with a minor amount black shale and coal, and a trace of sandstone.
----	970–980	Clay shale, medium- and medium-dark-gray, silty in part.
----	980–990	Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous, sericitic; carbonaceous particles.
----	990–1, 000	Clay shale, with some black clay shale, and a trace of coal.
----	1, 000–1, 010	Clay shale, with a trace of siltstone.
----	1, 010–1, 020	Clay shale, silty; with very argillaceous siltstone.
----	1, 020–1, 050	Clay shale, silty; a minor amount siltstone at the top.
----	1, 050–1, 060	Clay shale, with some siltstone.
----	1, 060–1, 070	Clay shale, with a trace of coal.
----	1, 070–1, 090	Clay shale, medium-dark-gray; and medium-gray very argillaceous siltstone.
----	1, 090–1, 120	Clay shale, with siltstone at 1,100–1,110 ft.
----	1, 120–1, 130	Siltstone; grades to clay shale.
----	1, 130–1, 150	Sandstone, light-gray, very fine-grained, very argillaceous and silty, noncalcareous; some siltstone at the base.
----	1, 150–1, 160	Siltstone, argillaceous; grades to silty clay shale.
----	1, 160–1, 250	Clay shale, very silty in upper part; a small amount siltstone at 1,170–1,180 and 1,230–1,240 ft, small amounts black clay shale at 1,180–1,190 and 1,200–1,220 ft, and small amounts medium-light-gray very fine-grained very silty argillaceous micaceous noncalcareous sandstone at 1,200–1,210 and 1,220–1,230 ft.
----	1, 250–1, 260	Siltstone, and clay shale.
----	1, 260–1, 290	Clay shale, silty at base; a small amount siltstone at 1,260–1,280 ft.
----	1, 290–1, 300	Siltstone, medium-light-gray, sandy, argillaceous, micaceous, noncalcareous; some clay shale.
----	1, 300–1, 330	Clay shale, silty in the lower part; siltstone in the bottom 10 ft.
----	1, 330–1, 340	Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, micaceous, noncalcareous. Electric log indicates clay shale.
----	1, 340–1, 350	Clay shale, with a small amount clay ironstone, and white very argillaceous bentonite.
----	1, 350–1, 370	Clay shale, with some siltstone in bottom 10 ft.
----	1, 370–1, 380	Clay shale with some sandstone, very sericitic.
----	1, 380–1, 390	Sandstone, as above; with some clay shale.
----	1, 390–1, 410	Clay shale, medium-dark-gray, slightly silty in part, noncalcareous. Top of Grandstand formation at 1,400 ft.
----	1, 410–1, 420	Clay shale and siltstone, a small amount sandstone.
----	1, 420–1, 450	Clay shale, medium and medium-dark-gray; a small amount siltstone at the top.
----	1, 450–1, 470	Clay shale, with some sandstone, and a minor amount siltstone.
----	1, 470–1, 475	No sample.
1	1, 475–1, 495	Recovered 20 ft: Microfossils very abundant. 4 ft 7 in., clay shale, medium-dark-gray, slightly silty, slightly micaceous; rare streaks of argillaceous siltstone and clay ironstone. Fair shaly cleavage indicates that the beds lie flat. 1 ft 7 in., claystone, dark-gray, not silty or micaceous; poor conchoidal fracture. 2 ft 3 in., siltstone, medium- to medium-light-gray, sandy in upper part, noncalcareous; many laminae and intercalations of clay shale. Pelecypod shell fragment from 1,487 ft identified by Ralph W. Imlay as *Lingula?* sp. 7 in., clay shale, medium-dark-gray; interlaminated with medium-light-gray siltstone. Grades into unit below.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		6 ft 7 in., claystone, medium-dark-gray, silty, noncalcareous; poor conchoidal fracture.
		3 ft, claystone, medium-gray, noncalcareous, hard; irregular intercalations of siltstone, some of which have shallow wavy contacts resembling ripple marks. Grades into unit below.
		1 ft 1 in., sandstone, very fine-grained, very argillaceous and silty, noncalcareous; abundant faint slightly carbonaceous and argillaceous laminae which are slightly crossbedded.
		4 in., limestone, medium-gray, silty, very argillaceous, dense.
2	1, 495–1, 509	Recovered 14 ft: Microfossils very abundant.
		3 ft 2 in., claystone, medium-dark-gray, very silty, noncalcareous, hard; irregular cleavage. Grades into unit below.
		5 ft 8 in., clay shale, medium-dark-gray, noncalcareous; shaly to subconchoidal cleavage. Less hard than claystone above. There is a streak of clay ironstone at the top.
		7 in., clay shale, medium-dark-gray; abundant intercalations of medium-light-gray siltstone; both noncalcareous. Beds essentially lie flat.
		4 ft 7 in., siltstone, medium-light-gray; interlaminated with medium-dark-gray noncalcareous clay shale; sandstone laminae in the lower part; some is faintly crossbedded and lenticular.
3	1, 509–1, 525	Recovered 16 ft: Microfossils very abundant.
		1 ft, siltstone interlaminated with clay shale, as above.
		4 ft, clay shale, medium-dark-gray, very slightly silty, noncalcareous; fair shaly cleavage indicates that beds lie flat. Grades into unit below.
		11 ft, claystone, medium-dark-gray, nonsilty; subconchoidal fracture; abundant pelecypod shells (including *Entolium* sp. and *Arctica*? sp., identified by Ralph W. Imlay) and an actinopterygian fish skeleton 1 in. long, identified by David H. Dunkle, U. S. National Museum.
4	1, 525–1, 528	Recovered 2 ft 7 in.: Microfossils common.
		2 ft 6 in., clay shale, as in core 3. A few small streaks of sandstone in the basal 1 in. of clay shale.
		1 in., sandstone, light-gray, salt and pepper, fine-grained, argillaceous, noncalcareous; sharp contact with overlying shale has ripplelike undulations.

Lithologic description—Continued

Core	Depth (feet)	Remarks
5	1, 528–1, 545	Recovered 17 ft: Microfossils common.
		1 ft 5 in., Sandstone, medium-light-gray, fine-grained with a few medium grains, slightly silty and argillaceous, noncalcareous; shaly cleavage (possibly caused by variations in clay content of matrix). Beds lie flat. Sand composed of subangular grains of clear and white quartz with some dark rock fragments and rare carbonaceous particles.
		1 ft 5 in., sandstone, as above, but with abundant intercalations and irregular laminae of medium-dark-gray clay shale. Abundant coaly intercalations and a ½-in. coal bed are in a 2-in. interval 1 ft below the top of this unit. Grades into unit below.
		1 ft, sandstone, as at top of core; poor shaly cleavage.
		1 ft 4 in., claystone, medium-dark-gray, silty, micaceous and noncalcareous, in upper part.
		3 ft, sandstone, as at the top of the core; poor to fair shaly cleavage. Beds lie flat. Quebracho staining suggests fair permeability in the bottom 1 ft. No cut or residue was obtained in CCl_4 from 1,533 ft. Effective porosity at 1,533 ft 10.62 percent; the rock is too friable for a permeability test.
		1 ft 5 in., sandstone, as above, but more massive and very fine-grained in part; common very fine laminae of coaly and argillaceous material.
		11 in., sandstone, as at top of core.
		1 ft 6 in., sandstone, fine-grained, some very fine grains; intercalations; laminae and rare thin beds of argillaceous, micaceous, and coaly material as in the 1 ft 5-in. bed above. The top 3 in. of sandstone is medium dark gray because of a concentration of carbonaceous particles.
		7 in, sandstone, as at top of core.
		3 ft 3 in., sandstone, as in 1 ft 6-in. bed above. A sample from 1,543 ft had no cut or residue in CCl_4. Effective porosity at 1,543 ft 12.62 percent; the rock is too friable for a permeability test.
		1 ft 2 in., sandstone, as at top of core.
6	1, 545–1, 565	Recovered 19 ft 9 in.: Microfossils common in claystone.
		2 ft 4 in., claystone; grades to clay shale with poor shaly cleavage; both are medium dark gray, noncalcareous, slightly micaceous, and silty in upper part.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		17 ft 5 in., sandstone, medium-light-gray, very fine- and fine-grained, noncalcareous; fair shaly cleavage, as at top of core 5. Quebracho staining suggests fair permeability at 1,548–1,552 and 1,559–1,560 ft. No cut or residue of oil was found in CCl_4 at 1,553 ft; a yellowish greasy stain was present as a residue at 1,563 ft, but no cut was noticeable at that depth. At 1,553 ft effective porosity 18.88 percent and air permeability 305 millidarcys; at 1,563 ft effective porosity 11.05 percent, and the rock is impermeable.
7	1, 565–1, 583	Recovered 18 ft: Microfossils abundant.
		9 in., sandstone, as in core 6 above.
		1 ft, claystone, medium-dark-gray, very slightly silty, noncalcareous; pyritized wood fragment.
		5 ft 3 in., sandstone, as in core 6 above, very fine- to fine-grained; poor shaly cleavage in the upper part, good in the lower part; thin streaks and intercalations of medium-dark-gray clay shale. No cut, but a yellowish greasy stain was recovered in CCl_4 at 1,570 ft. Effective porosity at 1,570 ft 16.44 percent; the rock is too friable for a permeability test.
		9 ft 8 in., clay shale, medium-dark-gray, interbedded and interlaminated with light-gray fine-grained sandstone and medium-gray siltstone, in approximately equal proportions. Laminae range from very even to very irregular and lenticular. Beds lie essentially flat.
		1 ft 4 in., sandstone, as at top of core.
----	1, 583–1, 590	Clay shale, silty; with fine-grained slightly silty sandstone, very slightly sericitic in part, as in cores above.
	1, 590–1, 634	Clay shale, dark- to medium-dark-gray, silty and very slightly silty. There is a trace of very fine-grained very slightly argillaceous nonmicaceous sandstone with sugary texture at 1,610–1,620 ft.
----	1, 634–1, 640	Clay shale; with some medium-light-gray very fine- to fine-grained very slightly silty noncalcareous sandstone; grains are composed of clear quartz with some white quartz.
----	1, 640–1, 645	Sandstone, as in sample above.
8	1, 645–1, 665	Recovered 20 ft: Microfossils abundant.
		6 in., claystone, medium-dark-gray, noncalcareous; silty laminae.
		12 ft 8 in., sandstone, as at base of core 6. Quebracho staining suggests fair permeability through most of this section except the lower 1 ft which shows no stain. A very faint cut and faint greasy stain were obtained in CCl_4 at 1,649 ft. Effective porosity at 1,649 ft 13.06 percent; the rock is too friable for a permeability test. At 1,654 ft effective porosity 13.89 percent and air permeability 8.5 millidarcys.
		6 ft 10 in., claystone, medium-dark-gray, slightly silty in part; upper one-third has scattered intercalations of siltstone showing swirly bedding. Fracture irregular.
9	1, 665–1, 670	Recovered 6 in: Microfossils abundant. Claystone, as at base of core 8.
----	1, 670–1, 710	Clay shale, medium-dark-gray, very slightly silty.
----	1, 710–1, 715	Clay shale, with some sandstone, medium-light-gray, fine-grained, silty, noncalcareous; composed of clear and white quartz with some rock fragments.
----	1, 715–1, 716	Sandstone, as above.
10	1, 716–1, 736	Recovered 17 ft 6 in.: Microfossils common.
		11 ft 2 in., sandstone, medium-light-gray, very fine- to fine-grained, very silty and argillaceous, slightly calcareous in part, massive. Sand is composed of subangular grains of clear and white quartz, with some dark rock fragments and rare carbonaceous particles. Slight variations in carbonaceous particles and argillaceous material cause faint very fine laminae through most of the section. Between 1,728 and 1,729 ft is a section of medium-gray slightly carbonaceous siltstone, with a 1-in. bed of very carbonaceous black siltstone 6 in. from the top. A very faint cut and very pale-yellow residue were obtained in CCl_4 from 1,719 ft. Effective porosity and air permeability at 1,719 ft 6.77 percent and <1 millidarcy, respectively.
		6 ft 4 in., claystone, as in cores 8 and 9. Siltstone lenticles present in upper 3 ft.
----	1, 736–1, 790	Clay shale, medium-dark-gray, very slightly silty; silty streaks in shale in bottom 10 ft.
----	1, 790–1, 800	Siltstone, medium-gray, sandy, noncalcareous; a minor amount clay shale and a trace of white slightly argillaceous bentonite.
----	1, 800–1, 810	Clay shale, siltstone, with a minor amount sandstone.
----	1, 810–1, 820	Siltstone, sandy; and silty siltstone, with some clay shale.
----	1, 820–1, 830	Clay shale, with some sandy siltstone, and a trace of silty sandstone.
----	1, 830–1, 870	Clay shale, medium-dark-gray, very slightly silty to silty; a minor amount sandstone and siltstone at 1,860–1,870 ft.
----	1, 870–1, 875	Sandstone, as in core 11 below; some clay shale.

Lithologic description—Continued

Core	Depth (feet)	Remarks
11	1,875–1,895	Recovered 20 ft: Microfossils rare. 2 ft 4 in., sandstone, as at the top of core 10, but very fine-grained in the top 8 in., below which is a 3-in. bed of medium-dark-gray claystone. 2 ft 8 in., Claystone,medium-dark-gray, interbedded with medium-gray faintly laminated siltstone. Beds are 2 to 8 in. thick, with equal proportions of siltstone and claystone. 7 ft, claystone, as in core 10; but with subconchoidal fracture in the basal 2 ft. 1 ft 2 in., clay shale, medium-dark-gray; similar to claystone above but with fair shaly cleavage. Beds lie essentially flat. 6 ft 10 in., sandstone, as in core 10; very faint cut and pale-yellow residue in CCl_4 at 1,889 ft. At 1,894 ft the effective porosity 14.22 percent, air permeability 18 millidarcys.
12	1,895–1,915	Recovered 19 ft 6 in.: Microfossils very rare. Sandstone, as at base of core 11; but with poor shaly cleavage and rare intercalations of clay shale in lower part. Quebracho staining suggests fair permeability in top 1 ft and from 1,899 to 1,901 ft. No cut was obtained, but a greasy stain was obtained from 1,898 ft, a faint greasy stain from 1,904 ft, and no stain from 1,914 ft. A very faint odor was noticed at 1,898 and 1,904 ft.

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)
1,898	12.10	11.5
1,904	13.61	32
1,914	12.10	25

Core	Depth (feet)	Remarks
13	1,915–1,935	Recovered 18 ft: Microfossils absent. Sandstone, medium-light-gray, fine-grained, silty and argillaceous, slightly calcareous from 1,927 to 1,930 ft, and noncalcareous elsewhere, massive; with rare faint slightly darker slightly more argillaceous sandstone laminae that are crossbedded in some places. In the upper half of the core, some units that are 2 to 6 in. thick and 1 to 3 ft apart show quebracho staining, which suggests better permeability for these units than for most of the sandstone. Beds lie approximately flat. The sandstone composed of subangular commonly frosted grains of clear quartz with some white quartz and rare dark rock fragments. Some grains have unweathered overgrowths of clear quartz, giving them a subhedral shape.

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)
1,917	7.36	Impermeable.
1,920	7.84	< 1.
1,920	10.01	Too friable.[1]
1,928	8.33	< 1.

[1] Core stained by quebracho.

Core	Depth (feet)	Remarks
14	1,935–1,955	Recovered 19 ft: Microfossils very abundant. 4 ft, sandstone, as in core 13 above; irregular scattered intercalations of clay ironstone; carbonaceous and argillaceous material between 1,937–1,938 ft. 3 ft 3 in., sandstone, as above but slightly coarser; a ¼-in. interval at top contains abundant small streaks of clay ironstone and carbonaceous material. Basal 1 in. of sandstone is very fine grained. At 1,940 ft effective porosity 13.45 percent, and the air permeability 24 millidarcys. 11 ft 9 in., claystone, medium-dark-gray, noncalcareous, slightly silty; irregular fracture; thin (less than 1 in.) beds of medium-gray siltstone in upper 6 in. and fine siltstone laminae in upper 1½ ft.
----	1,955–1,970	Clay shale, rarely slightly silty.
----	1,970–1,977	Sandstone, fine-grained, salt and pepper, silty, argillaceous, noncalcareous.
15	1,977–1,997	Recovered 19 ft 6 in.: Microfossils absent. Sandstone, medium-light-gray, fine-grained, silty, argillaceous, noncalcareous; massive except for a 6-in. bed at 1,988 ft that contains common carbonaceous partings. Quebracho staining in the upper 6 ft suggests slightly better permeability in that part of the core. Sandstone becomes slightly finer, very argillaceous and silty with depth. The sand is similar to that in core 13, but has fewer subhedral grains and more white quartz.

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)
1,978	2.77	Impermeable.
1,985	11.76	3.8.
1,992	8.28	Impermeable.

Lithologic description—Continued

Core	Depth (feet)	Remarks
16	1, 997–2, 014	Recovered 17 ft: Microfossils absent. Sandstone, as in core 15; grades from fine to very fine grained with depth. At 2,000 ft and 2,007 ft effective porosity 5.27 and 4.98 percent, respectively; the rock at both depths is impermeable.
17	2, 014–2, 017	Recovered 3 ft: Microfossils absent. Sandstone, medium-light-gray, very fine- to fine-grained, massive, noncalcareous: at 2,015 ft effective porosity 2.52 percent, and rock is impermeable.
18	2, 017–2, 033	Recovered 16 ft: Microfossils absent. 12 ft, sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, noncalcareous, massive. At 2,021 ft is a layer of rounded to well-rounded pebbles, ¼ to 1½ in. in diameter, composed of black and gray chert, light-gray hard noncalcareous sandstone, and one pebble of red and dark-green chert. A 4-in. bed of medium-gray very silty claystone is present 2 ft above the base of the sandstone. At 2,201 ft the effective porosity 3.37 percent, and rock is impermeable. 4 ft, siltstone, medium-gray, interbedded with medium-dark-gray noncalcareous claystone. Beds are 1 to 6 in. thick with approximately equal proportions of siltstone and claystone.
19	2, 033–2, 037	Recovered 4 ft: Microfossils absent. 10 in., sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, noncalcareous, massive. 6 in., claystone, medium-dark-gray, slightly to very silty; with laminae and intercalations of medium-dark-gray siltstone. 1 ft 6 in., sandstone, light-gray, fine-grained, slightly silty and argillaceous, noncalcareous; with a ½-in. bed of rounded claystone pebbles in medium-grained sandstone matrix 8 in. below the top. 1 ft 2 in., sandstone, light-gray, fine-grained, silty and argillaceous; but very fine grained, and with thin beds of medium-gray very argillaceous siltstone in the upper 6 in.
20	2, 037–2, 057	Recovered 20 ft: Microfossils very rare. Sandstone, medium-light-gray, very fine- to fine-grained, slightly argillaceous and silty, noncalcareous; quebracho staining (suggesting fair permeability) and shaly cleavage from 2,039 to 2,047 ft. Beds lie flat. Above and below those depths the sandstone is more massive, having only a few bedding-plane breaks. The sand is composed of subangular grains of clear quartz with some white quartz and dark rock fragments. At 2,042 ft. effective porosity 4.44 percent, and rock impermeable; at 2,050 ft porosity 10.6 percent, and permeability <1 millidarcy.
21	2, 057–2, 076	Recovered 15 ft: Microfossils very rare. Sandstone, as in core 20, slightly calcareous in part; shaly cleavage from 2,060 to 2,063 ft. Beds lie flat. Below 2,063 ft the sandstone is more massive but has common carbonaceous and argillaceous laminae, some which show slight crossbedding. A 1-in. bed of medium-dark-gray silty carbonaceous claystone is 2 ft above the base of core. At 2,062 ft effective porosity 11.97 percent, and rock is too friable for a permeability test.
----	2, 076–2, 095	Clay shale, medium-dark-gray, slightly silty in part; a very small amount of very fine-grained sandstone in the upper half.
----	2, 095–2, 113	Sandstone and clay shale.
22	2, 113–2, 133	Recovered 20 ft: Microfossils absent. 1 ft 3 in., sandstone, as above; common to abundant coaly streaks and partings. 18 ft 9 in., sandstone, medium-light-gray, very fine- to fine-grained, very silty and argillaceous, slightly calcareous in part, massive. Fine even carbonaceous laminae between 2,117 and 2,118 ft show some cross-bedding. At 2,120 and 2,129 ft effective porosity 5.75 and 3.48 percent, respectively; rock is impermeable at both depths.
23	2, 133–2, 138	Recovered 5 ft: Microfossils absent. Sandstone, as in core 22; at 2,137 ft effective porosity 11.50 percent, and air permeability < 1 millidarcy.
24	2, 138–2, 156	Recovered 18 ft: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, noncalcareous, massive, uniform. The sandstone is composed of angular to subangular grains of clear and white quartz, with some gray and dark rock fragments. Grain surfaces are commonly frosted. Carbonaceous particles and subhedral quartz grains are very rare. At 2,139 and 2,148 ft effective porosity 3.43 and 3.61 percent, respectively; rock is impermeable.
25	2, 156–2, 158	Recovered 2 ft: Microfossils absent. Sandstone, as in core 24. At 2,157 ft effective porosity 3.05 percent, and air permeability <1 millidarcy.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	2, 158–2, 168	Sandstone, fine-grained, silty, argillaceous, noncalcareous; a minor amount of clay shale.
----	2, 168–2, 182	Sandstone, very fine-grained, argillaceous, noncalcareous; with clay shale and a small amount of very sandy very slightly calcareous siltstone.
26	2, 182–2, 197	Recovered 15 ft: Microfossils abundant. 1 ft, sandstone, as in core 25; faint argillaceous carbonaceous laminae in the lower 4 in. 14 ft, sandstone, medium-light-gray, very fine-grained, interbedded with medium-dark-gray clay shale; the former grades to sandy siltstone with depth. The sandstone-siltstone beds are from 2 to 18 in. thick, and make up approximately two-thirds of the rock. They are noncalcareous, and commonly contain laminae and partings of argillaceous or carbonaceous material. The claystone beds are ½ to 6 in. thick. Beds lie approximately flat.
----	2, 197–2, 205	Clay shale, and very sandy siltstone.
----	2, 205–2, 235	Clay shale, medium-dark-gray, very slightly silty at top.
----	2, 235–2, 241	Sandstone, light-gray, fine-grained, silty, argillaceous, noncalcareous; a minor amount of medium-dark-gray clay shale.
27	2, 241–2, 261	Recovered 20 ft: Microfossils absent. 6 ft 8 in., sandstone, medium-light-gray, fine-grained, very slightly argillaceous, noncalcareous; shaly cleavage; quebracho staining suggests fair permeability. Rare fragments of carbonaceous plant remains in upper part. Beds lie flat. At 2,241 ft the effective porosity 9.66 percent, and sample was too friable for permeability test. 13 ft 4 in., sandstone, medium-light-gray, fine-grained, silty, argillaceous, noncalcareous, massive, uniform; grades to very fine- to fine-grained with depth. Faint laminae, caused by very slight variations in the quantity of carbonaceous particles, are present between 2,252–2,254 ft. At 2,252 and 2,261 ft effective porosity 7.90 and 6.69 percent, respectively; rock at both depths is impermeable.
28	2, 261–2, 282	Recovered 21 ft: Microfossils absent. Recovery from this core consists of fragments 1 to 4 in. in diameter (except for one a foot long) which were sent to the Fairbanks laboratory in two core boxes, one labelled 2,261–2,271 ft and the other 2,268–2,275 ft. The fragments are all medium- to medium-light-gray very fine- to fine-grained silty argillaceous noncalcareous uniform sandstone, apparently massive. Sand is composed of angular grains of clear and white quartz, with rare brown and dark rock fragments and rare mica. At about 2,270 ft effective porosity 5.55 percent, and rock is impermeable.
----	2, 282–2, 286	No sample.
----	2, 286–2, 300	Clay shale, medium-dark-gray, very silty.
----	2, 300–2, 330	Sandstone, medium-gray, fine-grained, salt and pepper; some very fine-grained very silty and argillaceous sandstone; siltstone in upper part; some clay shale.
29	2, 330–2, 349	Recovered 18 ft: Microfossils absent. 1 ft 2 in., sandstone, medium-light-gray, fine-grained, noncalcareous: it is coarser in the upper 2 in.; a 2-in. bed of medium-dark-gray clay shale 7 in. below the top. 3 ft 2 in., sandstone, medium-gray, very fine-grained, noncalcareous; abundant intercalations and partings of carbonaceous and micaceous material. A 1-in. bed of claystone is at the base. 8 in., sandstone; grades from medium-grained at the top to fine-grained at the base. 7 in., claystone, medium-dark-gray, silty, noncalcareous. 1 ft 2 in., sandstone, medium-light-gray, fine-grained, silty, argillaceous, noncalcareous; argillaceous laminae in lower 1 in. 8 in., claystone, as above; with ½-in. bed of sandstone near base. 10 ft 7 in., sandstone, medium-light-gray, very fine- and fine-grained, slightly to very silty and argillaceous, noncalcareous, massive. Slight variations in carbon content cause very faint laminae in the upper part of the sandstone. Beds lie approximately flat. A 2-in. bed of medium-dark-gray claystone is present at 2,340 ft. Slickensides and white calcite veinlets are present 1 ft above the base of the core; the bottom 1 ft of the core is slightly to very calcareous. At 2,338 and 2,348 ft effective porosity 5.23 and 5.37 percent, respectively; rock is impermeable.
30	2, 349–2, 368	Recovered 11 ft: Microfossils absent. 8 in., sandstone fragments, medium-light-gray, very fine- to fine-grained, noncalcareous; some slickensided or calcite-coated surfaces.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		10 ft 4 in., sandstone, as above; grades to very fine-grained, very silty at base; massive, with breaks dipping 20° to 30°. Scattered fragments and streaks of clay shale are present at 7, 4, 2, and 1 ft above the base of the core. Laminae of clay shale that dip 45° are present 2 ft above the base of the core. Slickensides are 4 ft above the base of the core.
----	2, 368–2, 375	Clay shale, with a small amount of siltstone.
----	2, 375–2, 385	Siltstone, medium-gray, very micaceous; minor amounts of clay shale and sandstone.
----	2, 385–2, 480	Clay shale, medium-dark-gray, slightly to very silty in part; a small amount of siltstone at 2,385–2,405 ft, traces of siltstone at 2,415–2,430 and 2,440–2,460 ft, traces of sandstone at 2,415–2,425 and 2,450–2,460 ft
----	2, 480–2, 490	Siltstone, medium-gray, very micaceous; a small amount of clay shale.
----	2, 490–2, 500	Clay shale; grades to siltstone.
----	2, 500–2, 510	Sandstone, fine-grained, noncalcareous, argillaceous, silty.
31	2, 510–2, 530	Recovered 19 ft: Microfossils absent. Sandstone, medium-light-gray, very fine- to fine-grained, noncalcareous, massive, uniform; becoming slightly finer grained with depth. Faint carbonaceous laminae between 3,514–3,515 ft; beds lie approximately flat. Slickensides are in the sandstone at 2,521 ft. At 2,511 and 2,521 ft effective porosity 9.50 and 0.25 percent, respectively; rock is impermeable.
32	2, 530–2, 547	Recovered 17 ft: Microfossils absent. Sandstone, as above; slightly darker and finer grained with depth; grades to medium-gray, very fine-grained, and silty at base. At 2,532 and 2,541 ft effective porosity 4.73 and 4.96 percent, respectively; rock is impermeable.
33	2, 547–2, 567	Recovered 20 ft: Microfossils absent. 5 ft 10 in., sandstone, as at base of core 32. Effective porosity at 2,552 ft 2.13 percent; rock is impermeable. 2 ft 2 in., claystone, medium-dark-gray; scattered thin beds and laminae of medium-gray siltstone and very fine-grained medium-light-gray sandstone, which increase in thickness with depth. 12 ft, sandstone, as in core 31; effective porosity at 2,562 ft 1.64 percent; rock is impermeable.
34	2, 567–2, 573	Recovered 6 ft: Microfossils absent. 2 ft, sandstone, as at base of core 33. 9 in., clay ironstone, medium-brownish-gray, nonsilty, very slightly calcareous; conchoidal fracture. 3 ft 3 in., sandstone, fine-grained; grades to very fine grained and from light to medium light gray with depth. A ½-in. layer of medium-dark-gray claystone pebbles is present at top of section, and very fine argillaceous laminae are present in upper part of sandstone. Carbonaceous streaks are present throughout. Beds lie approximately flat.
----	2, 573–2, 585	Sandstone, very fine-grained, very silty, as in core above; minor amount clay shale in lower part.
35	2, 585–2, 605	Recovered 20 ft: Microfossils absent. 11 ft 9 in., sandstone, medium-light-gray, very fine-grained, silty, argillaceous, very slightly micaceous, very slightly calcareous, massive. A layer of rounded gray chert pebbles ⅛ to ½ in. in diameter is at 2,588 ft; rare patches of flat pebbles of medium-dark-gray clay shale are in the lower half of the sandstone. Arctic Contractors' well geologist noted that the core bled oil at 2,583–2, 589, 2, 593–2, 594½ and 2,595½–2,596½ ft. A light-yellow cut and yellow residue were recorded in CCl_4 at 2,589 and 2,596 ft. There is no perceptible difference in the sandstone cores between the intervals which bled oil and those which did not. Samples from 2,589 and 2,596 ft were impermeable, with effective porosities of 9.31 and 10.50 percent, respectively. 6 in., claystone, medium-dark-gray, slightly silty; lenses of medium-gray siltstone. 5 in., sandstone, as above. 3 in., claystone, as above. 3 ft 2 in., sandstone, as above; bled oil from basal 3 in. 3 ft 11 in., claystone, medium-dark-gray, silty in part, irregular to poor shaly cleavage.
----	2, 605–2, 615	Clay shale, with a trace of siltstone and white bentonite.
----	2, 615–2, 625	Siltstone, medium-gray, slightly micaceous, very slightly calcareous; a minor amount of clay shale.
----	2, 625–2, 635	Clay shale; grades to siltstone, with a minor amount of sandstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	2, 635–2, 641	Sandstone, as in core 36; a trace of siltstone and clay shale.
36	2, 641–2, 661	Recovered 20 ft: Microfossils very abundant. 8 in., sandstone, as in core 35. 9 in., claystone, as at the base of core 35; abundant laminae of coaly material in bottom 2 in. 18 ft 7 in., sandstone, medium-light-gray, fine-grained, silty, argillaceous, very slightly calcareous in part, massive. It is composed of angular grains of clear and white quartz, and dark rock fragments. Most grains are frosted. Abundant intercalations of carbonized plant fragments are present at 2,645 ft and carbonaceous laminae at 2,653 ft. Carbonaceous and argillaceous laminae are common between 2,658–2,660 ft; they dip 5° or less. Patches of sandy clay ironstone are rare throughout. Sandstone at 2,646 ft had a very pale-yellow cut and light-yellow residue in CCl_4; sandstone at 2,656 ft had a light-yellow cut and yellow residue.

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)
2,644	12.00	4.5.
2,646	12.48	16.0.
2,646	14.00	11.5.
2,648	12.40	8.0.
2,650	8.67	0.
2,650	10.96	<1.
2,654	9.62	0.
2,656	7.17	Too friable.
2,656	8.17	0.
2,658	7.20	Too friable.

37	2,661–2,681	Recovered 14 ft: Microfossils very rare. 4 ft, sandstone, as at base of core 36, but with scattered coaly laminae which become common to abundant and grade from flat to finely undulating with depth. They dip 20° at the top, but the dip decreases with depth to flat at the base of the sandstone. A few clay ironstone nodules are in laminae in the lower 1 ft. Sandstone at 2,662 ft had a yellow cut and brownish-yellow residue in CCl_4; the well geologist reported that the core bled oil from 2,661 to 2,664 ft. At 2,662 ft effective prorosity 12.50 percent, air permeability <1 millidarcy. At 2,663 ft they are 12.75 percent and 2.8 millidarcys, respectively. 1 ft 3 in., sandstone, very fine-grained, with very fine even dark laminae which are the result of variations in quantity of carbonaceous and argillaceous matter. The laminae dip 30° at the top of the section, but curve gradually so that at the base, where they terminate abruptly against the underlying siltstone, they are nearly vertical (85°–90°) at one side of the core, and about 70° at the opposite side. At the top of the sandstone is a section of claystone, ½ in. thick on one side, and wedging out on the other, which fills the interval of rock between the flat-lying laminated sandstone above and the 30° dip of the sandstone below. 10 in., siltstone, medium-gray, very argillaceous, noncalcareous. Streaks of sandstone at the top show swirly bedding. Slickensides are near the top and bottom of the section; most are steeply dipping. The contact at the top of the section is sharp and dips approximately 50° in the opposite direction from the steeply dipping laminae of the overlying sandstone. 2 ft 2 in., sandstone, very fine- to fine-grained, very silty and argillaceous; with carbonaceous streaks in the lower part that dip 30° to 60°. The sandstone is calcareous in the lower 1 ft. ½ in., claystone, medium-dark-gray, slightly silty; slickensides parallel the bedding; sharp but irregular contacts are present at top and bottom. 1 ft 2 in., sandstone, medium-light-gray, very fine- to fine-grained, salt and pepper, argillaceous, silty, slightly calcareous; streaks of very fine sandstone in the upper part. 1 ft 9 in., sandstone, as above; but with coarse carbonaceous particles imparting an appearance of swirly bedding. Streaks (1 to 2 in. wide) of siltstone, and a 1- by 3-in. fragment of clay shale are in the central part of the sandstone, which grades to argillaceous siltstone and silty shale in in the bottom 2 in. 2 in., siltstone, medium-gray, sharply interlaminated with medium-dark-gray clay shale. Dip 7°. 1 ft 9 in., claystone, medium-dark-gray, silty; streaks of argillaceous siltstone. Steeply dipping slickensides present in claystone. Contact with underlying sandstone is sharp and resembles a ripple mark.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		10 in., sandstone, medium-light-gray, very fine- to fine-grained, slightly calcareous; patches and small streaks of carbonaceous material and clay shale. A ½-in. bed of abundant clay intercalations 2 in. below the top of the sandstone contains abundant *Inoceramus* shell fragments and one white quartz pebble ½ in. in diameter.
38	2, 681-2, 701	Recovered 15 ft 6 in.: Microfossils rare. 4 in., sandstone, medium-light-gray, very fine-grained, argillaceous and silty; very faint argillaceous silty laminae. Beds lie flat. 1 ft 8 in., clay shale, medium-dark-gray, noncalcareous; small lenses (1 to 2 in. thick) and laminae of medium-gray siltstone with sharp contacts resembling ripple marks. Beds lie flat. 1 ft 8 in., siltstone, medium-gray, very argillaceous, calcareous, faintly laminated; rare very thin (⅛ in. thick) beds of clay shale near the base. 4 ft, clay shale, as above. 7 in., sandstone, as above; grades to medium-gray sandy siltstone at base. 3 ft, claystone, medium-dark-gray, noncalcareous; irregular fracture. 3 ft, clay shale, as above; but with slightly thicker siltstone lenses. 1 ft 1 in., sandstone, as above; but very silty in upper 2 in. Laminae dip 3°. 2 in., clay shale, as above.
----	2, 701–2, 710	Sandstone, as in core above; with clay shale.
39	2, 710–2, 730	Recovered 10 ft: Microfossils absent. Sandstone, medium-gray, very fine- to fine-grained, silty, argillaceous, slightly micaceous, slightly calcareous in part, massive. A 1-ft bed 3 ft above the base is very silty and has argillaceous carbonaceous laminae at top and bottom. Sandstone is composed of angular to subangular commonly frosted grains of clear and white quartz, with scattered dark rock fragments. A sample from 2,720 ft had no cut and only a faint greasy stain as residue in CCl_4. At 2,720 ft effective porosity 7.05 percent; rock is impermeable.
----	2, 730–2, 760	Sandstone, medium-light-gray, argillaceous, noncalcareous.
----	2, 760–2, 770	Clay shale, with trace of siltstone. Top Topagoruk formation at 2,760 ft.
----	2, 770–2, 780	Siltstone, with some clay shale.
----	2, 780–2, 810	Clay shale, with good shaly cleavage, and some sandstone, salt and pepper, silty, slightly calcareous; fine grained at top, very fine grained in lower part.
----	2, 810–2, 820	Sandstone, very fine-grained; and clay shale.
----	2, 820–2, 830	Sandstone, very fine- to fine-grained; a small amount clay shale.
40	2, 830–2, 850	Recovered 17 ft 6 in.: Microfossils absent. 7 ft 6 in., claystone, medium-dark-gray, slightly silty in part; poor shaly cleavage to subconchoidal fracture. A 4-in. bed of light-gray fine-grained sandstone 3 ft below the top is very calcareous and contains *Ditrupa* sp. shell fragments at the top. A bed of medium-light-gray very fine-grained calcareous sandstone 7 in. thick, with faint flat-lying laminae, is 4½ ft below the top. Claystone contains rare siltstone lenticles. 2 ft 6 in., sandstone, medium-light-gray, very silty and argillaceous, calcareous; faint carbonaceous argillaceous lainae in lower part dip 5° or less. Fragments of medium-dark-gray clay shale are abundant in ¼-in. and 1-in. beds in the lower half of the sandstone. 7 ft 3 in., claystone, as above; a 10-in. bed of very fine-grained sandstone as above which has a ½-in. bed of claystone in the center and a ¼-in. bed at base. 3 in., claystone, as above.
----	2, 850–2, 880	Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, slightly calcareous; a small amount of clay shale in the lower part.
----	2, 880–2, 900	Clay shale, medium-dark-gray, very silty; grades to medium-gray very argillaceous siltstone with a minor amount of sandstone.
----	2, 900–2, 980	Clay shale, very silty in part; a minor amount of siltstone at the base and top, and some bentonite at 2,900–2,910 ft.
----	2, 980–3, 000	Clay shale; grades to siltstone.
----	3, 000–3, 010	Clay shale, with a minor amount of sandstone.
----	3, 010–3, 028	Sandstone, very fine-grained, silty, argillaceous, noncalcareous; a small amount of clay shale at the top.
41	3, 028–3, 048	Recovered 14 ft: Microfossils rare. 2 ft 6 in., sandstone, medium-light-gray, very fine- to fine-grained, argillaceous, silty, very slightly calcareous in part; scattered small streaks of medium-dark-gray clay. 6 in., siltstone, medium-gray, very sandy, very finely laminated; with a ½-in. bed of clay shale in the upper part. Grades into unit below.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		1 ft, sandstone, as above; but with more numerous streaks (up to 3 in. long) of clay suggesting swirly bedding. A 2-in. bed of clay shale is at the bottom of the sandstone. 10 ft., sandstone, medium-light-gray, very fine-grained, very argillaceous and silty, noncalcareous; some fine-grained sandstone; a few thin (1 to 2 in.) beds with faint rarely crossbedded laminae. Thin beds (½ to 2 in. thick), streaks, and intercalations of clay shale are throughout and increase gradually in size and abundance with depth. Small rounded bodies of sandstone (½ to 1 in. across, and ⅛ to ½ in. thick), with the same composition as the rest of the sandstone, are outlined by slightly darker and slightly more argillaceous matrix. They are in groups or singly through the sandstone, with their long axes parallel the bedding.
----	3, 048–3, 080	Clay shale, medium-dark-gray; becomes very silty with depth.
----	3, 080–3, 092	Sandstone, very fine-grained, argillaceous and silty, slightly calcareous in part.
42	3, 092–3, 112	Recovered 20 ft: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, very argillaceous and silty, slightly calcareous in part, massive; rarely faintly laminated. At 3,109 ft effective porosity 2.40 percent, and rock is impermeable. A 6-in. bed of interbedded medium-dark-gray clay shale and sandstone, with individual beds ⅛ to ½ in. thick, is at 3,097 ft; 6 in. below this is a 5-in. bed of medium - dark - gray noncalcareous slightly silty and micaceous claystone. A 4-in. bed of sandstone 1 ft above the base of the core contains a few thin intercalations of clay shale. *Ditrupa* sp. fragments are common throughout the core; pelecypod shells are also present, and a small fragment of an ammonite was found at 3,095 ft.
----	3, 112–3, 120	Siltstone, very sandy; similar to sandstone above; some clay shale.
----	3, 120–3, 160	Sandstone, very fine-grained, slightly calcareous; a small amount of clay shale.
----	3, 160–3, 210	Sandstone, as above; but with more clay shale, which increases to 50 percent with depth.
----	3, 210–3, 280	Clay shale, medium-dark-gray, slightly silty; a minor amount of medium-light-gray slightly sandy very slightly calcareous siltstone at the top.
----	3, 280–3, 293	Clay shale and sandstone, medium-light-gray, very fine-grained, very silty and

Lithologic description—Continued

Core	Depth (feet)	Remarks
		argillaceous, slightly calcareous; a minor amount of pale-blue-green slightly argillaceous and silty bentonite.
43	3, 293–3, 313	Recovered 20 ft: Microfossils common. 2 ft 2 in., siltstone, medium-gray, very sandy, slightly calcareous; abundant intercalations of claystone totaling about one-fourth of the rock. 1 ft 11 in., siltstone, as above; but faintly laminated and lacking clay. 1 ft 2 in., siltstone, as at top of core. 2 ft 8 in., siltstone, medium-light-gray, slightly calcareous; carbonaceous micaceous laminae which give good shaly cleavage to the rock. 7 ft 1 in., siltstone, with clay intercalations as at the top of the core. 6 in., clay shale, medium-dark-gray, slightly silty; poor shaly cleavage. 1 ft 5 in., siltstone, medium-gray, very sandy and argillaceous, calcareous, massive. 3 ft 1 in., siltstone, as at top of core.
----	3, 313–3, 320	Siltstone, with clay shale, and a small amount of sandstone.
----	3, 320–3, 330	No sample.
----	3, 330–3, 350	Clay shale; grades to siltstone, with a very small amount of fine-grained sandstone at the base.
----	3, 350–3, 358	Sandstone, medium-light-gray, very fine- to fine-grained, silty, argillaceous, micaceous, slightly calcareous.
44	3, 358–3, 378	Recovered 20 ft: Microfossils absent. 2 ft 2 in., sandstone, medium-light-gray, fine-grained; slightly calcareous at the top grading to very calcareous at the base. Scattered intercalations of carbonaceous and argillaceous material suggest a dip of 5° or less. 4 in., claystone, medium-dark-gray, nonsilty, very slightly calcareous in part; irregular fracture. 1 ft 6 in., claystone, medium-gray, nonsilty, noncalcareous; conchoidal fracture. 2 ft 1 in., claystone, medium-dark-gray, slightly calcareous, slightly silty. 12 ft 3 in., sandstone, medium-light-gray, fine-grained; grades to very fine-grained at base, silty, argillaceous, slightly calcareous to calcareous, slightly micaceous, massive. Rounded shale pebbles 1 in. in diameter are in a 2-in. bed at 3,362 ft with a few small (<1 in.) intercalations and pebbles of clay shale at 3,369–3,370 ft. At 3,368 ft effective porosity 3.23 percent, and carbonate content 22.35 percent by weight; at 3,373 ft they are 4.00 and 28.5, respectively. Both samples are impermeable.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		1 ft 8 in., siltstone, medium-dark-gray, very sandy and argillaceous, very slightly calcareous; abundant carbonaceous and biotite particles.
----	3, 378–3, 400	Clay shale, medium-dark-gray, silty; and medium-gray siltstone; grades to medium-light-gray very fine-grained slightly calcareous to calcareous sandstone.
----	3, 400–3, 410	Clay shale, with some siltstone.
----	3, 410–3, 470	Clay shale, medium-dark-gray, slightly silty in part; slightly calcareous at 3,450–3,460 ft.
----	3, 470–3, 490	Clay shale with minor amounts of medium-gray very argillaceous siltstone, and a trace of sandstone.
----	3, 490–3, 494	No sample.
45	3, 494–3, 514	Recovered 17 ft 6 in.: Microfossils very rare. 2 ft 7 in., sandstone, medium-light-gray, very fine-grained, silty, argillaceous, calcareous. Groups of rounded clay shale pebbles are present 1 ft and 2 ft below the top of the core. Pebbles range from small flakes to 2 in. in diameter. 3 ft 3 in., claystone, medium-dark-gray, silty, very slightly calcareous; irregular fracture. Rare thin (½ to 1 in.) crossbedded beds of siltstone. 8 in., siltstone, medium-light-gray, slightly calcareous; faint laminae give fair shaly cleavage; grades to very fine-grained very silty and argillaceous sandstone at base. 2 ft 3 in., claystone, as above, very silty. 8 ft 9 in., sandstone, very fine-grained, argillaceous, silty, calcareous, massive, uniform. Nearly vertical (88° or 89°) fractures, with patches of aragonite coating, split the sandstone core longitudinally for most of its length. At 3,509 ft effective porosity 5.5 percent, rock is impermeable, carbonate content 27.4 percent by weight.
46	3, 514–3, 532	Recovered 8 ft: Microfossils absent. 6 ft 4 in., sandstone, medium-light-gray, very fine-grained, silty, argillaceous, slightly calcareous, massive. At 3,520 ft effective porosity 6.89 percent, the carbonate content 16.12 percent by weight, and rock is impermeable. 1 ft 8 in., claystone, medium-gray, very silty, calcareous.
----	3, 532–3, 540	Clay shale, medium-dark-gray, noncalcareous; a small amount of sandstone.
----	3, 540–3, 550	Sandstone, medium-light-gray, very fine-grained, calcareous; a very small amount of clay shale.
----	3, 550–3, 560	Clay shale and sandstone.
----	3, 560–3, 570	Sandstone, with some clay shale, and a trace of pale-yellowish-white bentonite.
----	3, 570–3, 580	Clay shale, with a small amount of sandstone, and a minor amount of siltstone.
----	3, 580–3, 680	Clay shale, medium-dark-gray, slightly silty in part; common streaks of medium to medium-dark-gray very argillaceous slightly calcareous to calcareous siltstone.
----	3, 680–3, 740	Clay shale, medium-dark-gray, very slightly silty, noncalcareous; rare thin streaks of very argillaceous siltstone.
47	3, 740–3, 760	Recovered 12 ft 6 in.: Microfossils common. Claystone, medium-dark-gray, very slightly micaceous and silty, noncalcareous; irregular cleavage. Claystone between 3,742–3,747 ft badly broken and infiltrated with drilling mud; many of the fragments have slickensided surfaces. A flat-lying silt lamina one-quarter inch thick is at 3,755 ft. Pelecypod shell impressions scattered throughout include specimens identified by Ralph W. Imlay as *Thracia* cf. *T. kissoumi* McLearn and *Inoceramus* sp. juv. cf. *I. anglicus* Woods.

CORE ANALYSES

Samples from cores taken from Wolf Creek test well 3 were tested for porosity and permeability by methods described on page 441, and a few of the samples were analyzed for carbonate content. Results of these tests are given in the following table.

Analyses of core samples from Wolf Creek test well 3

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)
1,533	10. 62	Too friable.
1,543	12. 62	Too friable.
1,553	18. 88	305.
1,563	11. 05	0.
1,570	16. 44	Too friable.
1,649	13. 06	Too friable.
1,654	13. 89	8.5.
1,719	6. 77	<1.
1,894	14. 22	18.
1,898	12. 10	11. 5.
1, 904	13. 61	32.
1, 914	12. 10	25.
1,917	7. 36	0.
1,920	7. 84	<1.
1,920	10. 01	Too friable.
1,928	8. 33	<1.

Analyses of core samples from Wolf Creek test well 3—Con.

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)
1,940	13. 45	24.
1,978	2. 77	0.
1,985	11. 76	3.8.
1,922	8. 28	0.
2,000	5. 27	0.
2,007	4. 98	0.
2,015	2. 52	0.
2,021	3. 37	0.
2,042	4. 44	0.
2,050	10. 60	<1.
2,062	11. 97	Too friable.
2,120	5. 75	0.
2,129	3. 48	0.
2,137	11. 50	<1.
2,139	3. 43	0.
2,148	3. 61	0.
2,157	3. 05	<1.
2,241	9. 66	Too friable.
2,252	7. 90	0.
2,261	6. 69	0.
2,270	5. 55	0.
2,338	5. 23	0.
2,348	5. 37	0.
2,511	9. 50	0.
2,521	. 25	0.
2,532	4. 73	0.
2,541	4. 96	0.
2,552	2. 13	0.
2,562	1. 64	0.
2,589	9. 31	0.
2,596	10. 50	0.
2,644	12. 00	4.5.
2,646	12. 48	16.
2,646	14. 00	11.5.
2,648	12. 40	8.
2,650	8. 67	0.
2,650	10. 96	<1.
2,654	9. 62	0.
2,656	7. 17	Too friable.
2,656	8. 17	0.
2,658	7. 20	Too friable.
2,662	12. 50	<1.
2,663	12. 75	2. 8.
2,720	7. 05	0.
3,109	2. 40	0.
3,368 [1]	3. 23	0.
3,373 [1]	4. 00	0.
3,509 [1]	5. 50	0.
3,520 [1]	6. 89	0.

[1] The content of carbonate minerals, percent by weight, is 22.35 at 3,368 ft, 28.50 at 3,373 ft, 27.40 at 3,509 ft, and 16.12 at 3,520 ft.

HEAVY-MINERAL ANALYSIS

Preparation of samples is the same as in Square Lake test well 1. Robert H. Morris has determined that the zoned-zircon zone is represented in Wolf Creek test well 3 by samples from 1,940 to 3,520 feet. He reported that several samples from 1,540 to 1,940 feet have the general characteristics of the zoned-zircon zone but do not contain zoned zircons, so the uppermost limit of the zone is questionable. (See fig. 37.)

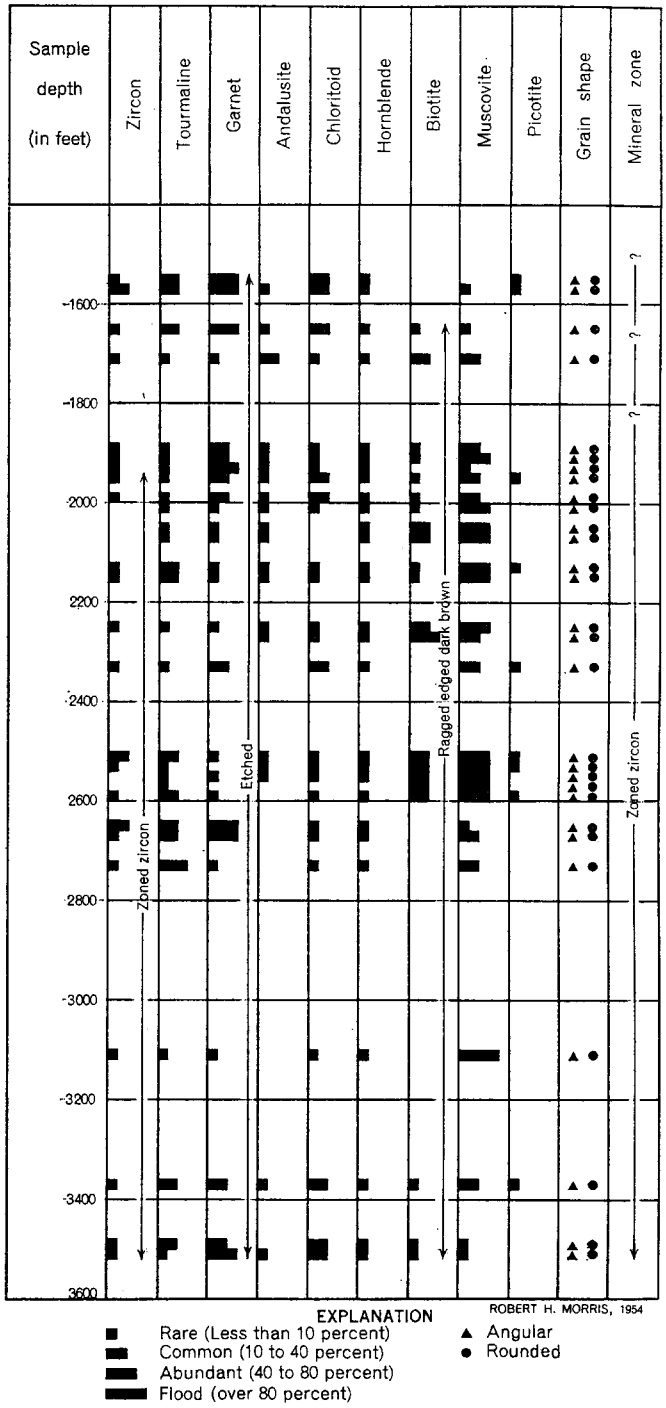


FIGURE 37.—Relative abundance of heavy minerals in Wolf Creek test well 3.

OIL AND GAS

OIL AND GAS SHOWS

Only minor shows of oil, and a small amount of gas, were found in Wolf Creek test well 3. Tests made for oil stain in CCl_4 are in given in the following table; gas production is given in the paragraph on formation tests.

Core samples from Wolf Creek test well 3 tested for oil stain with carbon tetrachloride

Depth (feet)	Cut	Residue
1, 533	None	None.
1, 543	do	Do.
1, 553	do	Yellowish greasy stain.
1, 563	do	None.
1, 570	do	Yellowish greasy stain.
1, 649	Extremely pale	Faint greasy stain.
1, 719	do	Very pale yellow.
1, 889	Very pale	Pale yellow.
1, 898	None	Faint greasy stain.
1, 904	do	Do.
1, 914	do	None.
1, 978	do	Very faint greasy stain.
2, 000	do	None.
2, 015	do	Do.
2, 042	do	Very pale yellow stain.
2, 062	do	Pale yellow stain.
2, 120	do	None.
2, 137	do	Do.
2, 148	do	Faint greasy stain.
2, 157	do	Do.
2, 241	do	Do.
2, 252	do	Very faint greasy stain.
2, 261	do	Do.
2, 270	do	Faint greasy stain.
2, 338	Straw colored	Yellow.
2, 348	Very pale straw colored	Do.
2, 511	None	None.
2, 521	do	Greasy stain.
2, 532	do	Do.
2, 541	do	None.
2, 552	do	Pale yellow stain.
2, 562	do	Very faint greasy stain.
2, 589	Light yellow	Yellow.
2, 596	do	Do.
2, 646	Straw colored	Pale yellow.
2, 656	Light yellow	Yellow.
2, 662	Yellow	Brownish.
2, 720	None	Faint greasy stain.

FORMATION TESTS

Twelve formation tests using the Johnston formation tester were made in Wolf Creek test well 3. The first 3 tests and the sixth test recovered some gas, and the last 2 tests had a very little free oil on top of the oil-emulsion drilling mud; the other 6 tests recovered only drilling mud. In each case the hole was open from the packer to the current total depth. A description of the tests follows:

Test 1, 1,528.5–1,545 feet.—A 7¼-inch packer was set at 1,528.5 feet with 16.5 feet of tailpipe, including 5 feet of perforated pipe, and a 5/16-inch bean. The tool was open 150 minutes and a moderate blow of gas was noted at the surface before the tool was closed for 70 minutes; the flow pressure was zero, and closed-in pressure built up to 450 psi. Seventy feet of drilling mud was recovered, the salinity of which (440 parts per million) was affected by quebracho. The flow of gas was measured by a 2-inch critical flow prover as follows:

⅜-in. orifice, 169,700 cu ft per day at 37.5 psi and 38.5° F.
¼-in. orifice, 174,000 cu ft per day.
½-in. orifice, 161,200 cu ft per day at 13 psi and 40° F.

The tests were run in the order listed above. The apparent flow, which decreased with time, may be due to the depletion of sand area adjacent to the hole.

Test 2, 1,548.5–1,565 feet.—A 7½-inch packer was set at 1,548.5 feet with 16.5 feet of tailpipe, including 5 feet of perforated pipe, and a 5/16-inch bean. The tool was open 273 minutes and closed for 10 minutes. The flow pressure was zero, and the closed-in pressure built up to 500 psi. Ten feet of drilling mud was recovered, and the gas flow was measured by a critical flow prover. The gas flow rates were:

⅜-in. orifice, 394,800 cu ft per day at 107 psi and 44° F.
½-in. orifice, 406,000 cu ft per day at 55 psi and 44° F.
¾-in. orifice, 444,600 cu ft per day at 20 psi and 44° F.

Test 3, 1,647–1,670 feet.—A 7¼-inch packer was set at 1,647 feet with 20.5 feet of tailpipe, 9 feet of which were perforated, and a 5/16-inch bean. The tool was open 242 minutes, and a slight blow increased to a light blow after 1 hour. The packer pulled loose during an attempt to record the closed-in pressure. Estimated bottom hole pressure was 375 psi. Seventy feet of drilling mud was recovered; its salinity of 400 parts per million chlorides was affected by quebracho. A critical flow prover measured the following flow of gas:

⅛-in. orifice, 74,100 cu ft per day at 188 psi and 36° F.
¼-in. orifice, 87,300 cu ft per day at 44 psi and 43° F.

Test 4, 1,878–1,915 feet.—A 7¼-inch packer was set at 1,878 feet with 37 feet of tailpipe, including 18 feet of perforated pipe. A 5/16-inch bean was open 183 minutes and closed for 16 minutes. A very slight blow of gas came to the surface. The bottom-hole pressure did not reach equilibrium in 16 minutes, and the maximum recorded pressure was 400 psi. The large amount of fluid recovered, 230 feet of gas-cut mud, may have been the result of spudding the packer to shear the pin.

Test 5, 1,978–2,017 feet.—A 7¼-inch packer was set at 1,878 feet with 37 feet of tailpipe, including 18 feet of perforated pipe. A 5/16-inch bean was open 131 minutes and closed for 38 minutes. No gas came to the surface, and both the flowing and the closed-in bottom-hole pressure were zero. Fifty feet of mud was recovered.

Test 6, 2,038–2,076 feet.—A 7¼-inch packer at 2,038 feet had 38 feet of tailpipe, including 18 feet of perforated pipe, below it. A 5/16-inch bean was open 288 minutes and closed for 28 minutes. A weak blow increased to moderate in 3 hours. Recovered 176 feet of water-cut mud with salinity of 3,135 ppm sodium chloride. Salinity of drilling mud was 500 ppm. Flowing pressure was zero, and the closed-in pressure was 850 psi. The critical flow prover measured the flow of gas as follows:

⅛-in. orifice, 120,000 cu ft per day at 315 psi and 37° F.
¼-in. orifice, 257,700 cu ft per day at 158 psi and 40° F.
⅜-in. orifice, 284,500 cu ft per day at 73 psi and 40° F.

Test 7, 2,243–2,282 feet.—A 7¼-inch packer was set at 2,243.8 feet with 38.2 feet of tailpipe, including 18 feet of perforated pipe. The 5/16-inch bean was open 150 minutes and was not closed. No gas came to the surface, and the flowing pressure was zero. Fourteen feet of mud was recovered with 500 ppm salinity.

Test 8, 2,512–2,547 feet.—A 7¼-inch packer was set at 2,512 feet; 34.9 feet of tailpipe below the packer included 22 feet of perforated pipe. The 5/16-inch bean was open 158 minutes and was not closed. No gas came to the surface, the flowing pressure was zero, and only 6 feet of mud with 500 ppm salinity was recovered.

Test 9, 2,587.5–2,605 feet.—A 7¼-inch packer at 2,587.5 feet had 17.5 feet of tailpipe, including 8 feet of perforated pipe below it. A 5/16-inch bean was open 270 minutes and not closed. No gas came to the surface; the flowing pressure was zero, and 10 feet of mud was recovered.

Test 10, 2,643.5–2,661 feet.—A 7¼-inch packer was set at 2,643.5 feet with 17.5 feet of tailpipe, including 8 feet of perforated pipe, below it; a 5/16-inch bean was used. The tool was open 210 minutes, and a very weak blow increased slightly during that time. Flowing pressure was zero; after being closed in for 30 minutes the pressure increased to 450 psi but did not reach equilibrium. Nine hundred feet of mud entered the tool when the retaining valve became plugged.

Test 11, 2,647.4–2,681 feet.—A 7¼-inch packer was set at 2,647.4 feet with 33.6 feet of tailpipe, including 21.2 feet of perforated pipe and a 5/16-inch bean. The tool was open 193 minutes, and closed for 62 minutes; flowing pressure and closed-in pressure were zero. A very slight blow was recorded during the test, and 70 feet of mud was recovered with 2 quarts of free oil floating on top. The API gravity of the free oil was determined at the well site to be 34.5°. The crude oil from Umiat used in the mud emulsion had a gravity of 32.6°.

Test 12, 2,644–2,681 feet.—A 7¼-inch packer was set at 2,644 feet with 37 feet of tailpipe, including 24 feet of perforated pipe, below it. The tool was open 360 minutes, and a very slight blow of gas was noted. Flowing pressure and closed-in pressure were zero; 90 feet of oil-cut mud was recovered with 2 gallons of free oil floating on top.

OIL AND GAS ANALYSES

Four samples of gas and one sample of oil from the formation tests were submitted for analysis to the U. S. Bureau of Mines at Bartlesville, Okla. The gas was 89.1 to 99.4 percent methane, with a very small amount of nitrogen and propane; other constituents made up less than 1 percent of the gas. The oil was brownish green and had an API gravity of 34.0° and a Saybolt Universal viscosity of 42 seconds at 110°F. Results of the gas analyses from Wolf Creek test well 3 are given in the following table.

Analyses of gas from Wolf Creek test well 3

[Analyses by the U. S. Bureau of Mines]

Constituent	Test 1, 1,528–1,545 feet (percent)	Test 2, 1,548–1,565 feet (percent)	Test 3, 1,647–1,670 feet (percent)	Test 6, 2,038–2,076 feet (percent)
Methane	98. 6	99. 4	96. 1	97. 0
Ethane	. 1	. 1	. 2	. 3
Propane	. 7	. 3	. 9	. 7
Normal butane	Trace	. 0	. 0	. 1
Normal pentane	. 0	. 0	. 0	. 1
Hexanes plus	. 0	. 0	. 0	. 1
Nitrogen	. 5	. 2	2. 8	1. 6
Oxygen	Trace	Trace	Trace	Trace
Argon	. 0	Trace	Trace	Trace
Btu per cu ft [1]	1, 019	1, 016	1, 000	1, 019

[1] Calculated gross Btu per cu ft, dry, at 60°F and 30 in. of mercury.

The following table gives an analysis of an oil sample from Wolf Creek test well 3.

Analysis of an oil sample from formation test 12 from Wolf Creek test well 3 at 2,644–2,681 feet

[General characteristics of sample: Sp gr, 0.855; sulfur, 0.15 percent; Saybolt Universal viscosity at 100°F, 42 sec; gravity, 34.0°API; pour point, below 5°F; color, brownish green]

Distillation by Bureau of Mines routine method

Fraction	Cut at— °C	Cut at— °F	Percent	Sum (percent)	Specific gravity [1]	Gravity °API at 60°F	Correlation index	Aniline point (°C)	Saybolt Universal viscosity at 100°F	Cloud test (°F)
Stage 1.—Distillation at atmospheric pressure, 759 mm Hg. First drop, 133°C (271°F)										
1	50	122								
2	75	167								
3	100	212								
4	125	257								
5	150	302								
6	175	347	6.7	6.7	0.791	47.4		42.6		
7	200	392	9.3	16.0	.809	43.4	34	53.4		
8	225	437	14.2	30.2	.823	40.4	35	58.8		
9	250	482	14.7	44.9	.838	37.4	37	61.4		
10	275	527	12.6	57.5	.852	34.6	39	63.7		
Stage 2.—Distillation continued at 40 mm Hg										
11	200	392	6.2	63.7	0.871	31.0	44	67.2	42	5
12	225	437	7.1	70.8	.875	30.2	42	73.0	49	30
13	250	482	5.6	76.4	.879	29.5	40		64	40
14	275	527	5.5	81.9	.890	27.5	42		100	50
15	300	572	5.0	86.9	.898	26.1	43		195	55
Residuum [2]			12.3	99.2	.918	22.6				

Approximate summary

Constituent	Percent	Specific gravity	Gravity °API	Saybolt Universal viscosity
Light gasoline				
Total gasoline and naphtha	16.0	0.801	45.2	
Kerosene distillate	14.2	.823	40.4	
Gas oil	37.6	.852	34.6	
Nonviscous lubricating distillate	11.4	0.876–.890	30.0–27.5	50–100
Medium lubricating distillate	5.5	.890–.899	27.5–25.9	100–200
Viscous lubricating distillate	2.2	.899–.902	25.9–25.4	Above 200
Residuum	12.3	.918	22.6	
Distillation loss	.8			

[1] Specific gravity at 60°F compared with water at 60°F.
[2] Carbon residue (Ramsbottom) of residuum, 1.8 percent (Conradson equivalent, 2.6 percent): carbon residue of crude, 0.2 percent.

LOGISTICS

Personnel and housing.—Three men were employed at the well in supervisory positions. They were the drilling foreman, a petroleum engineer, and a geologist. The other 23 members of the permanent crew included 16 men in the drilling crews (2 drillers, 2 derrickmen, 7 floormen, 2 firemen, 2 heavy-duty-equipment mechanics, and 1 crane operator). Also employed were 2 cooks, 2 kitchen helpers, 2 tractor operators, and 1 man who combined the duties of warehouseman, first-aid expert, and storekeeper. Temporary workers such as carpenters, laborers, welders, radio repairmen, electricians, and Schlumberger engineers were sent from Umiat as they were needed.

Five jamesway huts were used for dormitories, and three others for a kitchen galley and a combination store and dormitory. Of the 12 wanigans used, 1 of each served as boiler room, geological laboratory, machine shop, Schlumberger room, generator room, utility room, and lavatory; others were used for storage rooms for food, chemicals, and cement.

Vehicles and heavy equipment.—A Caterpillar

tractor train hauled 1,575 tons of material to the well site in late May and early June 1952. The drilling equipment (see p. 444) was brought from Square Lake test well 1, and other supplies came from Umiat. Vehicles used in the vicinity of the well were three weasels, a D8 Caterpillar tractor, a small crane (TD–9 cherrypicker), a swing crane, and an LVT.

Fuel and lubricant consumption.—The total amount of gas and oil used was 49,755 gallons of diesel oil, 1,961 gallons of gasoline, 802 gallons of lubricating oil, 530 pounds of thread-lubricating grease, and 243 pounds of other lubricating greases.

DRILLING OPERATIONS

DRILLING NOTES

The derrick was mounted on pilings over a concrete cellar that was 8 feet square and 4 feet deep. Information on drilling operations, presented below, has been summarized from data compiled by Everette Skarda and Robert D. Rutledge, petroleum engineers for Arctic Contractors.

Notes from drilling records

Depth (feet)	*Remarks*
121	After the hole was reamed to a diameter of 22 in. and to a depth of 119 ft, an attempt was made to set the casing. The pipe would not go below 88 ft, so it was pulled and the hole reamed to 121 ft with a 17-in. reamer. Four joints (86 ft) of 16-in. inner-diameter casing was set at 107 ft, with the 2 middle joints jacketed with 23⅝-in. casing and cemented with 100 sacks of Cal-Seal. The top of the cement was found 10 ft below the cellar floor, and 25 more sacks were used to cement around the annulus.
654	After cleaning out tight spots in the hole with a reamer, 624 ft of 10¾-in. 55-lb N–80 seamless casing was set at 625 ft and cemented with 210 sacks of High Early cement.
1,456	The drilling mud was changed from water-base to 30 percent oil-emulsion mud.
3,760	Two cement bridges, the first of 120 sacks of cement from 1,447 to 1,735 ft, and the second, of 30 sacks, from 554 to 621 ft, were put in the hole. After a ½-in. steel plate was welded to the casing collar, with a 4-in. plugged pipe on top that extended 2 ft above ground, the hole was abandoned.

DRILL AND CORE BITS

About a fifth of the footage in Wolf Creek test well 3 was cored with Reed conventional core bits; 90.6 percent of the rock cored was recovered. Of the 42 core bits used, 40 were hard-formation bits, and the other 2 were soft-formation bits. All were 7½ inches in diameter, except for two 6¼-inch hard-formation bits.

Several types of drill bits were used, including hole-openers, 3 types of Hughes bits, and 2 Smith bits. Thirty-seven bits were used in all; of these, 30 were 9⅞ inches in diameter and the others were 12¼ to 26 inches in diameter.

The bits used in the hole and the footage to which each drilled are shown on the graphic log (pl. 30). Where drill bits were used for reaming through cored intervals, they are shown as having only drilled. This was done to avoid confusion from short alternating intervals of drilling and reaming by a single bit.

DRILLING MUD

Wolf Creek test well 3 was drilled to 1,456 feet with water-base Aquagel mud; at that depth the mud was changed to 30 percent oil emulsion, which was used to complete the well. The hole was maintained in good condition, with little or no caving. The following discussion of the mud is by Everette Skarda (written communication, 1952), the petroleum engineer at Wolf Creek test well 3.

The oil phase was a paraffin-base crude from Umiat test well 5, topped to approximately 325° F. The resulting fraction had an API gravity of 32.6° and a viscosity of 9 cps (centipoises) at 60° F. A 30 percent emulsion was used.

The base mud was an Aquagel-water mixture containing approximately 15 pounds of Aquagel per barrel of water. The initial make-up mix consisted of 3 pounds per barrel quebracho (sodium tannate), 0.5 pound per barrel caustic soda, and 30 percent by volume of topped crude oil. Care was used when adding the sodium tannate to prevent viscosity from becoming too high due to the oil phase. The 6 to 1 quebracho to caustic ratio was decreased for the first 100 pounds of quebracho and increased thereafter to insure sufficient quebracho to prevent a high viscosity. The crude was added over two complete circulation trips and was very nearly emulsified at the end of the addition. It was not necessary to add Aquagel after the initial base had been mixed, the native clay providing for any additional mixes as the hole progressed. It may be necessary, however, to add Aquagel in the event the drilling rate is accelerated.

Drilling rates were slow, allowing a maximum amount of hydration of the highly bentonitic native clays. It was found that the lower the percentages of oil in the emulsion, the greater was the hydration. Viscosities rose to 150 Marsh funnel seconds in one case while drilling through a highly bentonitic section.

Viscosity control was the major consideration in handling the oil-base mud. The initial mix had a viscosity of 90 Marsh funnel seconds, a pH of 11.3, a water loss of 2.0–2.5 cc API, and a gel strength of 0–8 grams Stormer. These properties were usually maintained for 2 or 3 days of drilling. By the end of that time the viscosity would have risen to the 115–130 range. In most cases sufficient hole had been made to require an addition to the circulating system. Only water, quebracho, caustic, and oil were added to lower the viscosity to near the original value.

The following table records the characteristics and additives of the drilling mud used in the test well.

Drilling-mud characteristics and additives, Wolf Creek test well 3

Depth (ft)	Weight (lb per cu ft)	Viscosity (Marsh funnel seconds)	Water loss (cc API)	Temperature (°F)	Pyrophosphate (lb)	Aquagel (sacks)	Baroid (sacks)	Caustic soda (lb)	Driscose (lb)	Quebracho (lb)	Oil (bbl)
0							100				
107	75	60									
110	75	58									
200						13					
363	74	49		60		7				100	
440						6					
516	75	42	7	60							
652	79	50	7	60							
695						10				100	
840						20					
941	74	46	7	60		3					
1,121	74	46	7	70							
1,277	73	44	6	70		3				75	
1,350						2				75	
1,411	80	45	6	70							
1,456	80	44	7.3	70			5				45
1,470							70				
1,495	81	110	1.6	72							
1,528	79	130	1.5	60							
1,545	79	128	1.6	62	15			10		75	
1,563	80	150	1.7	60			60				7
1,582	80	95	1.9	60			10				
1,600							3				
1,621	83	105	2.0	70							
1,668	82	125	2.2	76							
1,692	80	135	1.8	64				4		30	3
1,735	82	106	1.9	70			3				
1,809	83	97	2.3	74				5		30	3
1,860								5		30	3
1,895	80	95	2.4	77							
1,915	82	94	2.2	68			6				
1,930							5				
1,955	82	97	2.2	72							
1,983	83	110	2.4	67			5				
2,000								10		60	6
2,015	82	86	2.4	70			3				
2,035	82	94	2.4	60							
2,052	82	90	2.5	62			9				
2,073	84	112	2.4	64				5		30	
2,125	83	95	2.5	62				10		60	6
2,135	84	97	2.5	64			8				
2,180	84	95	2.5	64			3				
2,195							4				
2,241	84	100	2.4	63			3	10		75	6
2,260							3				
2,280	84	100	2.5	62			3				
2,330	85	114	2.4	60							
2,340							5				
2,365	85	115	2.4	62			6				
2,412	85	105	2.2	65				20		100	
2,478	86	113	2.4	70				10		30	3
2,505							5				
2,516	85	90	2.4	62							
2,564	86	100	2.4	60			3				
2,585	86	98	2.4	65				20		100	6
2,611	86	105	2.5	60			3				
2,640							3				
2,660	87	105	2.5	62			3				

Drilling-mud characteristics and additives, Wolf Creek test well 3—Continued

Depth (ft)	Weight (lb per cu ft)	Viscosity (Marsh funnel seconds)	Water loss (cc API)	Temperature (° F)	Pyrophosphate (lb)	Aquagel (sacks)	Baroid (sacks)	Caustic soda (lb)	Driscose (lb)	Quebracho (lb)	Oil (bbl)
2,680	87	110	2.4	58			3				
2,685							5				
2,705	87	110	2.5	59							
2,720							5	8		50	
2,740	87	115	2.4	59			3				
2,810	87	111	2.5	65			3				
2,830								10		60	6
2,850	86	95	2.5	60			3				
2,897	87	96	2.4	62			3				
2,962	87	115	2.4	66							
3,000								5		30	3
3,112	90	120	2.6	63			3				
3,190	89	90	2.5	65				10		60	6
3,210							9				
3,245	89	86	2.6	66							
3,310	90	100	2.7	63			3				
3,358	90	100	2.8	62							
3,372							5				
3,400	90	104	2.5	66							
3,470	91	110	2.5	63			3				
3,515	91	115	2.6	63							
3,532	91	100	2.6	60			9	8		50	
3,550							5				
3,582	91	95	2.6	63			5				
3,629	92	105	2.6	65							
3,681	92	105	2.6	67			5				
3,750	93	112	2.6	66			5				
3,760	93	95	2.5	60	125		8			5	

HOLE DEVIATION

For the first 1,000 feet, the hole was only 15 minutes off vertical; below that depth it deviated 40 to 55 minutes, except at 1,610 feet where the deviation reached 1°. Measurements were made with a Totco recorder.

ELECTRIC LOGGING

Electric logs, made by the Schlumberger Well Surveying Corp., from Wolf Creek test well 3, recorded spontaneous-potential, long- and short-normal, and microlog curves between 107 and 3,752 feet. The first three curves are shown on the graphic log (pl. 30). Selected intervals from the microlog, shown in figure 38, present curves recorded through beds of sandstone which appear to be slightly to moderately permeable. Five electric log runs were recorded at the following depths:

Run	Depth (feet)	Run	Depth (feet)
1	107– 654	4	2,397–2,696
2	654–1,623	5	2,600–3,752
3	1,623–2,466		

Run 4 overlaps 69 feet of run 3, and run 5 overlaps 96 feet of run 4. In each case the earlier run is shown on the graphic log.

LITERATURE CITED

Goddard, E. N., and others, 1948, Rock-color chart: Washington, D. C. National Research Council.

Robinson, F. M., 1958, Test wells, Gubik area, Alaska: U. S. Geol. Survey Prof. Paper 305–C.

Collins, F. R., 1958, 1957, Test wells, Umiat area, Alaska: U. S. Geol. Survey Prof. Paper 305–B.

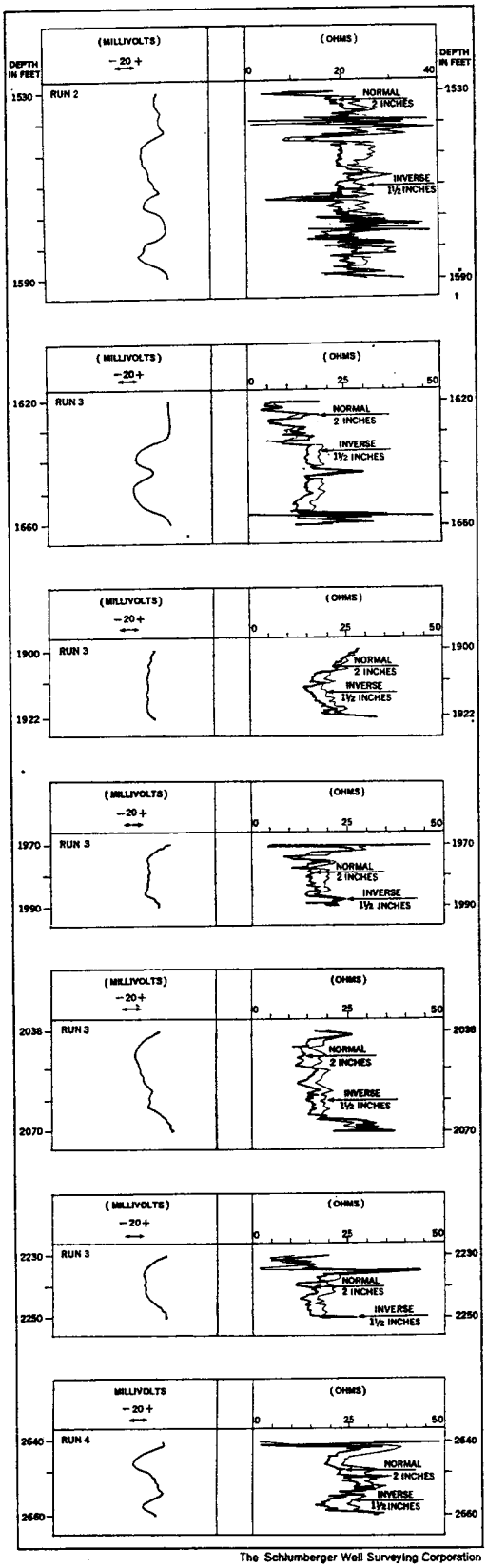


FIGURE 38.—Selected intervals from the microlog of Wolf Creek test well 3.

MICROPALEONTOLOGY OF SQUARE LAKE TEST WELL 1 AND THE WOLF CREEK TEST WELLS, NORTHERN ALASKA

By HARLAN R. BERGQUIST

The 3 test wells drilled in the Wolf Creek area and Square Lake test well 1 penetrated 3 fossiliferous zones in Upper and Lower Cretaceous rocks (Colville and Nanushuk groups). Beds of the Upper Cretaceous Seabee formation were penetrated in Wolf Creek test well 2 to a depth of 130 feet and are identified by a concentration of a few arenaceous Foraminifera, which I found elsewhere concentrated in the lowest beds of the formation. The Turonian age of the formation (and of the section penetrated) can be inferred, because these beds are equivalent to the section below the *Borissiakoceras*-bearing shales of the Seabee formation in the Umiat area (grye, *in* Payne and others, 1951).

In Square Lake test well 1 no fossils were found to ascertain the age of the upper part of the section, but samples from 522 to 550 feet yielded a few broken tests of *Spiroplectammina webbei* Tappan and specimens of Foraminifera that range through the Colville group. In much of the section, scattered specimens of Colville species were found, but in the interval from 1,260 feet to 1,620 feet a slight concentration of species occurs that is characteristic of the lower part of the Seabee formation in other areas. Thus, because the beds appear to be a part of the Seabee formation, a Turonian age is inferred for the section.

Beneath the Seabee formation is the Ninuluk formation, which was penetrated in each of the Wolf Creek area wells and in Square Lake test well 1. The Ninuluk formation can usually be identified by abundant tests of *Gaudryina canadensis* Cushman and *Trochammina rutherfordi* Stelck and Wall, as these species constitute a faunal zone in the formation in areas of outcrop. Tests of *G. canadensis* and *T. rutherfordi* occurred sparingly in Wolf Creek test wells 1 and 2 and in Square Lake test well 1. A more definite faunal zone was suggested in Wolf Creek test well 3, where specimens of *T. rutherfordi* were fairly numerous. This species was originally described from the Kaskapau formation of Cenomanian age in the Peace River area of western Canada (Stelck and Wall, 1955), and its presence in abundance thus infers a Cenomanian age for the Ninuluk formation. Research on the megafossils of the outcropping Ninuluk formation by Ralph W. Imlay has led to his conclusion (written communication, 1956) that a Cenomanian age can be established because the fossils are identical with those from the Dunvegan formation of Alberta and British Columbia.

Beds of the nonmarine Killik tongue of the Chandler formation underlie the fossiliferous beds of the Ninuluk formation. This tongue was penetrated in each of the Wolf Creek Wells and in Square Lake test well 1. Below the Killik tongue the *Verneuilinoides borealis* faunal zone was penetrated. This zone, named from the dominant species of Foraminifera, is extensive and is several thousand feet thick. Within its limits are included the upper part of the Torok formation and the Tuktu and Grandstand formations of the outcrop areas as well as the rocks in the subsurface which Mrs. Collins defines as Grandstand and Topagoruk formations. The Albian age of the fauna is ascertained from the presence of a few European and Canadian Albian Foraminifera and the work of Imlay on the associated megafossils (Imlay, R. W., written communication, 1956).

Apparently only the top of the *Verneuilinoides borealis* zone was penetrated in Wolf Creek test wells 1 and 2, but nearly 2,400 feet of beds in this zone was drilled in Wolf Creek test well 3. In Square Lake test well 1 more than 1,500 feet (2,475–3,987 feet) of beds within the *Verneuilinoides borealis* faunal zone was drilled.

SQUARE LAKE TEST WELL 1

TULUVAK TONGUE OF THE PRINCE CREEK FORMATION (0–700 FEET)

In the predominately nonmarine sandstone (of the Tuluvak tongue of the Prince Creek formation) penetrated in the upper part of the Square Lake test well, carbonaceous prints of plants occurred in several samples. Plants from two cores (at 458 and 585 feet) were identified by Roland W. Brown as *Metasequoia cuneata* (Newberry) Chaney. In the lower part of the Tuluvak tongue (522–550 feet), above the lower occurrence of *M. cuneata*, is a thin foraminiferal section, the base of which is 150–175 feet above the base of the tongue. The Foraminifera are mostly specimens of *Haplophragmoides rota* Nauss with a few specimens of *Trochammina ribstonensis* Wickenden, *Gaudryina irenensis*

Stelck and Wall, and a few fragments of *Spiroplectammina webberi* Tappan. These species are found in the Colville group (Upper Cretaceous).

SEABEE FORMATION (700–1,885 FEET)

A few specimens of arenaceous Foraminifera were found in core and ditch samples in the upper 120 feet of the Seabee formation, but the succeeding 280 feet of beds was largely nonfossiliferous. *Inoceramus* prisms were abundant in a sample from 1,140–1,150 feet and were present in most ditch samples throughout the formation. Fishbones were found in a few samples from 1,120–1,230 feet. A radiolarian (*Cenosphaera* sp.) was common at 1,180–1,190 feet, and the pyritic casts of another species (*Zonodiscus* sp.) were common in a sample from 1,570–1,580 feet. A few specimens of Radiolaria were found in several other samples between the occurrences mentioned above.

A few species of Foraminifera were found in samples from 1,220–1,600 feet and in a few samples from the lower part of the Seabee formation. *Haplophragmoides rota* was most frequent in occurrence and was common in cores from two intervals (1,286–1,296 feet and 1,451–1,478 feet). *Saccammina* sp. was abundant in the upper core, and tests of *Gaudryina irenensis* were common in samples from the lower core. Specimens of *Textularia gravenori* Stelck and Wall, *Praebulimina carseyae* (Plummer) and *Neobulimina canadensis* Cushman and Wickendon also occurred in the core samples from 1,451–1,478 feet.

Most of the cores from 1,637–1,735 feet were barren, but *Inoceramus* prisms were in cores from 1,675–1,685 feet and from 1,735–1,765 feet. Tests of *Gaudryina irenensis* were common in the core from 1,755–1,765 feet, and a few specimens of *Praebulimina carseyae* were also found. Samples from the cored section from 1,841–1,878 feet had only *Inoceramus* prisms, and the basal few feet of the section (core from 1,878–1,885 feet) was barren.

NINULUK FORMATION AND KILLIK TONGUE OF THE CHANDLER FORMATION (1,885–2,475 FEET)

Abundant specimens of *Gaudryina canadensis* Cushman and *Trochammina rutherfordi* Stelck and Wall in the bottom foot of a core from 1,878–1,886 feet indicate the top of the Ninuluk formation. In the succeeding core (1,886–1,896 feet), *T. rutherfordi* was common. Within the Ninuluk formation in general these two species occur as a faunal zone from which nearly all other Foraminifera are excluded. In the Square Lake well this faunal zone is extremely limited; most of the samples from an interval of more than 460 feet were unfossiliferous. Because of this condition I prefer to consider the strata from the base of the Seabee formation (Colville group) to the top of the *Verneuilinoides borealis* faunal zone as undifferentiated beds of the Ninuluk formation and the Killik tongue of the Chandler formation. A plant fossil at 2,346 feet and a few specimens of *G. canadensis* Cushman from the remainder of the core (2,340–2,347 feet) came from a marine intertongue within the Killik tongue.

VERNEUILINOIDES BOREALIS FAUNAL ZONE (2,493 FEET TO TOTAL DEPTH)

In the Square Lake well the *Verneuilinoides borealis* faunal zone is very poorly developed. The number of species is small, being not more than 15 or 16 in all, of which only 3 or 4 species were found in any degree of abundance.

Common specimens of *Verneuilinoides borealis* Tappan and a few other questionably identified specimens of Foraminifera occurred in a core sample from 2,493–2,505 feet. These are the highest occurrence of species of the *V. borealis* faunal zone. Small specimens of *V. borealis* were abundant in a core sample from 2,840–2,853 feet. In cores from 3,192–3,211 feet, specimens of *Verneuilinoides borealis* and fragments of *Ammobaculites* n. sp. were common, and *Haplophragmoides topagorukensis* Tappan was abuandant. *Ammobaculites* n. sp. also occurred in lower cores, including the bottom-hole core (3,978–3,987 feet) in which a few specimens of *Nanushukella umiatensis* Tappan were also found. Other cores were barren.

WOLF CREEK TEST WELL 1

NINULUK FORMATION (10–445 FEET)

In this well more than half the samples were fossiliferous, but the microfauna was small, the number of specimens relatively few, and some samples contained only *Inoceramus* prisms. Specimens of *Trochammina rutherfordi* Stelck and Wall and *Gaudryina canadensis* Cushman make up most of the microfauna and comprise a faunal zone in the Ninuluk formation. Specimens of *T. rutherfordi* were common in two samples.

Below the *Gaudryina canadensis – Trochammina rutherfordi* faunal zone, most of the section to 1,080 feet was barren of microfossils except for 2 ditch sample occurrences of *Inoceramus* prisms and rare occurrences of *Trochammina rutherfordi*. In a core sample from 1,080–1,084 feet and in ditch samples from 1,205–1,215 feet and 1,293–1,300 feet, specimens of *Verneuilinoides borealis* were found. A few specimens of *Miliammina awunensis* Tappan occurred in a sample from 1,350–1,360 feet, and common specimens of *Verneuilinoides borealis* and a few specimens of *Gaudryina canadensis* and *Miliammina awunensis* were found in the 2 lowest

samples studied (1,435–1,445 feet, and 1,485–1,490 feet).

From the foregoing data it is evident that a large part of the section below the *Gaudryina canadensis–Trochammina rutherfordi* faunal zone is very likely a part of the Killik tongue of the nonmarine Chandler formation, but the fossiliferous core sample and ditch samples indicate marine intertongues (probably from the Grandstand formation) in the beds below 1,000 feet. Certainly these samples are from a part of the *Verneuilinoides borealis* faunal zone, but the last two samples from the test well are from more fossiliferous beds of the same faunal zone.

WOLF CREEK TEST WELL 2

SEABEE FORMATION (25–130 FEET)

In the 7 ditch samples taken from the interval of rocks assigned to the Seabee formation was a small fauna of 3 species of Foraminifera, *Saccammina* sp., *Haplophragmoides rota* Nauss, and *Gaudryina irenensis* Stelck and Wall. Tests of *Haplophragmoides rota* were common in a sample from 35–45 feet, and *Saccammina* sp. was common in a sample from 65–75 feet. In other occurrences the Foraminifera were rare; at 120–130 feet abundant *Inoceramus* prisms prevailed. The next sample, from 130–140 feet, had a small but distinctly different fauna that marks the top of the Ninuluk formation.

The few Foraminifera found are not alone distinctive of the Seabee formation, as they range throughout the Colville group. A study of outcrop samples, however, indicates that each of these species occurs most frequently in the lower part of the Seabee formation. Thus as a small assemblage, these species, and sometimes 1 or 2 others with them, can be considered fairly characteristic of the lower beds of the Seabee formation.

NINULUK FORMATION (130–650 FEET)

Specimens of *Trochammina rutherfordi* Stelck and Wall were common in a sample from 140–150 feet and indicate an abrupt change in fauna. In lower samples this species occurred in rare numbers; but in a sample from 605–615 feet, specimens were abundant. A few tests of *Gaudryina canadensis* Cushman were associated in the latter sample. In another sample 2 specimens of *T. rutherfordi* were found, but the samples from 655 to 1,330 feet were barren.

Trochammina rutherfordi and *Gaudryina canadensis* are indicative of beds of the Ninuluk formation as they are usually the only species found in them. In this test well at least the interval from 130–650 feet can be assigned to the Ninuluk formation.

Other than carbonaceous material and minute fragments of coal in a few samples, beds throughout the interval below the assumed base of the Ninuluk formation were unfossiliferous except for 4 samples. A sample from 1,330–1,335 feet contained 4 specimens of *Verneuilinoides borealis* Tappan and a specimen of *Involutina* sp. A specimen of *Miliammina awunensis* Tappan occurred with 2 fragments of *Gaudryina canadensis* Cushman in a sample from 1,470–1,475 feet, and common specimens of *Verneuilinoides borealis* and *Gaudryina canadensis* occurred in a sample from 1,545–1,550 feet. Two specimens of *Verneuilinoides borealis* were found in a sample from 1,565–1,570 feet. These few fossils are from marine intertongues of the *Verneuilinoides borealis* faunal zone in an otherwise nonfossiliferous section of the nonmarine Chandler formation.

WOLF CREEK TEST WELL 3

NINULUK FORMATION (30–510 FEET)

The interval of rock from 30 to 510 feet is dominated by *Gaudryina* and *Trochammina*. In nearly every sample from 50 to 510 feet, specimens of *Trochammina rutherfordi* Stelck and Wall were found; in several samples a few specimens of *Gaudryina canadensis* Cushman occurred. In more than one-third of the samples, *T. rutherfordi* was common to abundant. *Inoceramus* prisms were present in most of the samples.

KILLIK TONGUE OF THE CHANDLER FORMATION (510–1,400 FEET)

Barren samples throughout much of the interval from 510 feet to the cores starting at 1,475 feet suggest beds of the Killik tongue, but on the basis of lithologic changes the base of the Killik has been placed at 1,400 feet. In one sample in the lower part of the tongue (1,300–1,310 feet), specimens of *Verneuilinoides borealis* Tappan and *Gaudryina canadensis* Cushman were common and suggest a tongue of the *Verneuilinoides borealis* zone. Rare occurrences of a few Foraminifera in 3 or 4 samples higher in the Killik tongue may be in part contamination from the Ninuluk formation, but some are apparently from intertongues from the *Verneuilinoides borealis* faunal zone.

VERNEUILINOIDES BOREALIS FAUNAL ZONE

Nearly 2,300 feet of section in this well is entirely within the *Verneuilinoides borealis* faunal zone, and approximately 250 feet of the overlying section has thin beds of the zone interbedded with the Killik tongue. Although the fauna is small in the beds within the *Verneuilinoides borealis* zone, the specimens of individual species occur in large numbers in some samples. In most of the samples in a continuously cored section that extends from 1,475 to 1,583 feet, specimens of *V. bore-*

alis, *Miliammina awunensis* Tappan, and *Gaudryina canadensis* were common to abundant. In one sample *Trochammina rutherfordi* was common, and the species was sparingly present in others. Specimens of *Haplophragmoides topagorukensis* Tappan, *Psamminopelta subcircularis* Tappan, and *Saccammina* sp. occurred in several samples. A tiny fish skeleton and a few mollusk shells were recovered from a core at 1,515–1,525 feet.

Abundant specimens of *Psamminopelta subcircularis* came from a core from 1,655–1,670 feet, and specimens of *Verneuilinoides borealis*, *Miliammina awunensis*, *Trochammina rutherfordi*, and *Gaudryinella irregularis* Tappan were common in the same sample. In a core from 1,944–1,955 feet, specimens of *V. borealis* were very abundant, and *Haplophragmoides topagorukensis* was common. The latter species was also common in a core from 2,182–2,197 feet and greatly outnumbered the few specimens of *V. borealis* and fragments of *Ammobaculites* sp. found in it.

Several cores in sandy beds within the upper part of the faunal zone were barren of fossils. These cores were from 1,885–1,944 feet, most of the section from 1,977–2,072 feet, and the intervals of rock from 2,113–2,158 feet, 2,241–2,275 feet, 2,330–2,359 feet, and 2,510–2,605 feet.

Below a barren sandy section (2,510–2,605 feet) one core (2,642–2,661 feet) had in a thin shale bed at the top an abundance of tests of *Gaudryinella irregularis*, and common numbers of *Verneuilinoides borealis*, *Miliammina awunensis*, and *Gaudryina canadensis*.

In the lower part of the *Verneuilinoides borealis* faunal zone in this well, very few Foraminifera were found in the beds below 2,760 feet. The upper cores had no microfossils but did have *Inoceramus* prisms and fragments of the tubes of *Ditrupa* sp. (2,830–2,840 feet). A few Foraminifera occurred in cores from 3,028–3,043 feet, 3,293–3,313 feet, and 3,494–3,514 feet, and the bottom-hole core (3,740–3,760 feet). *Haplophragmoides topagorukensis*, *Verneuilinoides borealis*, and *Miliammina awunensis* occurred in each of these cores, but in only the last core was a species (*Haplophragmoides topagorukensis*) common. Mollusk shells from the basal core have been identified by Ralph Imlay as *Thracia* sp. and *Inoceramus* sp. (cf. *I. anglicus* Woods) and from a core from 3,092–3,112 feet as *Entolium* sp. and *Lemuroceras* sp.

BIBLIOGRAPHY OF THE MICROPALEONTOLOGIC STUDY

Cushman, J. A., 1946, Upper Cretaceous Forminifera of the Gulf Coastal Region of the United States and adjacent areas: U. S. Geol. Survey Prof. Paper 206, 241. p.

Nauss, A. W., 1947, Cretaceous microfossils of Alberta: Jour. Paleontology, v. 21, no. 4, p. 329–434.

Payne, T. G., and others, 1951, Geology of the Arctic Slope of Alaska: U. S. Geol. Survey Oil and Gas Inv. Map OM–126, sheet 3.

Stelck, C. R., and Wall, J. H., 1954, Kaskapau Foraminifera from Peace River area of western Canada: Prov. of Alberta, Res. Council Rept. no. 68.

——— 1955, Foraminifera of the Cenomanian *Dunveganoceras* zone from Peace River area of western Canada: Prov. of Alberta, Res. Council Rept. no. 70.

Tappan, Helen, 1957, Cretaceous Foraminifera from northern Alaska: U. S. Natl. Mus. Bull. 215.

Wickenden, R. T. D., 1932, New species of Foraminifera from the Upper Cretaceous of the prairie provinces: Royal Soc. Canada Proc. and Trans. 3d ser., v. 26, sec. 4.

INDEX